SIXTH FRAMEWORK PROGRAMME
PRIORITY FP6-2004-IST-4
Situated and Autonomic Communications (SAC)

Contract for:

INTEGRATED PROJECT

Annex I - "Description of Work"

Project acronym: ANA
Project full title: Autonomic Network Architecture
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Related to other Contract no.: *N/A*

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0 Abstract

This document is an amendment to the existing description of work document of our project. The amendment or update of the existing document reflects the changes that have been made to the workplan due to new findings and achievements of the project.
In a short summary, the proposed changes are the following:

- During the course of this project, we determined some new research directions that we decided to follow on. They are very much in line with what has been discussed also in the last review. Basically, we think that the platform we are developing is not only useful for autonomic networking concepts but also for future networking in general. The ANA platform offers a very flexible mean to develop new communication concepts beyond traditional IP networking.
  To be able to pursue this direction further and also to promote the platform itself, we had to relocate budget from different partners to strengthen the core development team. Note that we were able to do so without giving up other tasks. In particular, we were able to use resources from additional cost partners to perform the promised work and will use the available budget then for implementation and integration tasks.
- Also, ue to the feedback received from the reviewers and the research community in general, we will strengthen the development activities in ANA. These changes are reflected in newly created tasks as well as PM reallocations.
- In total, we created 3 new tasks:
  - Task 1.6 ANA Core Development
  - Task 4.3 Integration of the diverse software components
  - Task 4.4 Testing autonomicity
- To better promote the results of the project, we will strengthen the dissemination efforts. That means that we also plan to provide demonstration tools and more frequent software releases.

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1 Project Summary

This Integrated Project aims at exploring novel ways of organizing and using networks beyond legacy Internet technology. The ultimate goal is to design and develop a novel network architecture that enables flexible, dynamic, and fully autonomic formation of network nodes as well as whole networks. It will allow dynamic adaptation and re-organisation of the network according to the working, economical and social needs of the users. This is expected to be especially challenging in a mobile context where new resources become available dynamically, administrative domains change frequently, and the economic models may vary.

The scientific objective of this proposal is to identify fundamental autonomic network principles. Moreover, this project will build, demonstrate, and test such an autonomic network architecture. The key attribute is that such a network scales in a functional way that is, the network can extend both horizontally (more functionality) as well as vertically (different ways of integrating abundant functionality). The challenge addressed in this project is to come up with a network architecture and to fill it with the functionality needed to demonstrate the feasibility of autonomic networking within the coming 4 years.

2 Project Objective

The scientific objective is to identify autonomic networking principles that enable networks to scale not only in size but also with respect to their functionality. A functionally scaling network is a synonym for an evolving network; It also includes the many self-x attributes i.e., integration and steering of functionality. New functions must be integrated; otherwise we do not have scaling of functionality, only function accumulation.

Functional scaling is different from the usual meaning of *network scaling* where pure numbers of nodes are looked at which need to be integrated. By scaling functionality we mean that a network is able to extend both horizontally (more functionality) as well as vertically (different ways of integrating abundant functionality).

We clearly express the view that a new Internet architecture has to attack the “core” of the network. This research is thus different from ubiquitous and pervasive networking (which looks into functionally enriched networking environments): although a new network architecture has to be able to stretch also to small devices, its main purpose is to cover that diversity, including core network routers, in both dimensions presented above (size wise and functional scaling). This research also differs from traditional overlay approaches that attempt to build new networking structures at the edges – on top of existing Internet networks – without support from the network core and routers themselves. We seek a new network architecture that is able to provide customized and autonomic networks on demand in a native way.

2.1 The Internet Case

The Internet as well as the OSI model are examples of a functionally non-scalable approach: both are based on the premise of factoring out functionality. Networking concepts were sought which are able to stretch from local scale to global size, from slow links to high-speed trunks, from PDAs to supercomputers. The “canonical set” of protocols collected in the Internet-Suite has done a surprisingly good job so far. Today however, limitations of this one-size-fits-all approach have become visible, which can be linked to the failure of the Internet to scale in a functional way at the networking level.

The place where the Internet has envisaged and endorsed functional scaling is the application layer. This is also where remarkable breakthroughs have been achieved and variety was obtained: DNS, eMail, Web, VoiP and P2P are the highlights to mention here.

The networking layer of the Internet has not aimed at functional scaling, by design. It has evolved through a patch style which has not added variety: Additions were made in a stealth way and have not dared to change things. We refer here to the introduction of the hidden routing hierarchy with AS, CIDR or MPLS as well as other much less successful projects like RSVP, multicast, mobile IP or MANET. IPv6 has aimed for a real change but has not yet succeeded to replace the dominant IPv4. Even if it eventually will, it does NOT add significant functional extensions - IPv6 proudly announces that end users should not experience any difference. Several basic Internet concepts, like for example the amalgam of address and node location, needs to be revisited.

2.2 Trends

The term “Internet de-construction” has been used to characterize the efforts to understand the main concepts underlying the success of the Internet, but also its shortcomings. In a functional scaling perspective, a first trend is that current layered networking software needs to be *atomized* in smaller units that can be recombined.

A second trend is *diffusion* where functionality that belonged to one layer beforehand will be used in the future at arbitrary places inside a protocol stack, requiring the introduction of autonomic organization principles. A third trend is that of *sedimentation* i.e., the tendency of services to form compounds either with other required services or with the service clients.

As a case consider logical naming that currently is embodied by DNS at the application layer. In an autonomic network we imagine that distributed name spaces (for logical names, but also addresses or even content) will organize themselves - using P2P technologies - inside the network and inside network segments like a sensor community. Name translation and mapping functions will belong to the autonomic network, permitting the creation of naming or addressing overlays where needed e.g., for backward compatibility or for inter-stitching different network turfs.

In an autonomic communications system we envisage an environment that supports variety. This variety shall not be limited to "technology plugins" like different physical transmission schemes that can be exchanged, or different transport protocols, which the Internet already supports. A central believe and paradigmatic change, with respect to the Internet, is that the AC network will not build on uniformity and universal compatibility. There might be many functions inside an AC network which are *not* compatible with each other. Moreover, backward compatibility shall not be a criterion for admitting or rejecting extensions at the networking layer. Instead, we aim at a network that is "forward compatible": Variations and novel recombination of existing network functionality will coexist and possibly compete, various degrees of local and even global customization can be provided, and opportunistic as well as engineered network configurations will be supported. Only the capacity of the network to be polyfunctional *and* to handle this multitude of options in an integrated way justifies the label "autonomic". The Internet will become an instance of many other possible network personalities.

2.3 Objectives

ANA has two complementary objectives that iteratively provide feedback to each other: a scientific objective and a technological one.

Scientific objective: To identify *fundamental autonomic networking principles* that enable networks to scale not only in size but also in functionality. The main premise of our work is that a *functionally* scaling network is a synonym for an evolving network which includes the various self-x attributes essential to autonomic communication such as self-management, self-optimization, self-monitoring, self-repair, and self-protection. The hypothesis is that, due to these self-x attributes, such functional scaling will naturally lead to networks that are not only richer in functionality but which also scale in size. Scientific research in ANA will explore the "Internet de-construction" trends of functional atomization, diffusion and sedimentation (see Section 2.2) that will replace the current static layering approach.

A new Autonomic Network Architecture will emerge as a result of this research. This architecture will provide the framework for network function re-composition. The goal is produce an architectural design that enables flexible, dynamic and fully autonomic formation of large-scale networks in which the functionalities of each constituent network node are also composed in an autonomic fashion. This architecture must allow dynamic adaptation and re-organisation of the network according to the working, economical and social needs of the users. Moreover, it must support mobile nodes and multiple administrative domains.

Technological objective: The second premise in ANA is that the only way to make new ideas and concepts succeed is to put them into practice. Therefore, ANA takes on the challenge of not only producing original scientific research results and a novel architectural design, but also showing that they work in real situations, and using the experience gained experimentally as feedback to refine the architectural models and other research results.

The technological objective of ANA is therefore to build an experimental autonomic network architecture, and to demonstrate the feasibility of autonomic networking within the coming 4 years.

As a first step, a network based on the predominant infrastructure of Ethernet switches and wireless access points will be built. The goal is to demonstrate self-organization of individual nodes into a network. The design of such network should potentially scale to large network meshes in the range of 10^5 active (routing) elements. Obviously, the consortium alone will not have resources to literally build a network of 10^5 nodes. In order to show scalability, three approaches are envisaged: a) overlay for interconnecting the participating sites, b) simulations, and c) a distributed open collaborative approach similar to successful initiatives such as “SETI@Home”, “Folding@Home”, to include external experimentators and to disseminate ANA results.

The second step, using insights from the first effort, will loosen the constraints and permit wired and multihop wireless heterogeneous devices to be integrated in an autonomic way. Here the focus is on the self-organization of networks into a global network. The rationale for a two phase approach is that an architecture can only be developed and its quality be validated if more than one case is explored.

These two (scientific and technical) objectives complement and reinforce each other in a tight feedback loop: Prototypes of research results will be implemented in the testbed at an early stage, such that preliminary experimental results can be used as a feedback to steer and refine the architectural design and to obtain more accurate and realistic research results. The research part will shape the testbed in order to maintain it at the fore-front of technology. To help the long term visions to materialize, ANA uses the testbed as an investigative research vehicle while remaining committed to the far looking character of the situated and autonomic networking initiative.

Over the first two project years, we identified some new research directions that complement the vision and the objectives as formulated in 2005. During the implementation of the generic networking framework, it became evident that the platform we are about to develop is not only suitable for autonomic network architectures, but also represents a very flexible platform for Future Internetworking Platforms in general. To address this more general objective, we proposed to shift resources to new tasks that promote the ANA core platform and strengthen the development and engineering team. As a side effect, this measure also further improves the dissemination strategy with regard to visibility and impact.

3 Participants List

Participant Role	Number	Participant Name	Participant short name	Country	Date enter project	Date exit project
CO	1	Eidgenoessische Technische Hochschule Zurich	ETHZ	Switzerland	month 1	month 48
	2	University of Basel	UBasel	Switzerland	month 1	month 48
	3	NEC EUROPE LTD.	NEC	UK	month 1	month 48
	4	University of Lancaster	ULanc	UK	month 1	month 48
	5	Fraunhofer Gesellschaft zur Foerderung der angewandten Forschung	Fokus	Germany	month 1	month 48
	6	Université de Liege	ULg	Belgium	month 1	month 48
	7	Université Paris VI Pierre et Marie Curie	UPMC	France	month 1	month 48
	8	National and Kapodistrian University of Athens	NKUA	Greece	month 1	month 48
	9	Universitetet I Oslo	UiO	Norway	month 1	month 48
	10	Telekom Austria	TA	Austria	month 1	month 48
	11	University of Waterloo	UWater	Canada	month 1	month 48

To fulfill the challenging objectives of the ANA integrated project proposal, a coherent team of leading European research institutes and international industrial partners has been carefully designed. Each partner has been specifically selected for its ability to address a subset of the tasks defined by the ANA project. The key driver of the creation of this consortium has been the gathering of the complementary expertise of all the partners. This consistent and multi-disciplinary set of research and industrial entities will eventually contribute to bringing the EU to a leading role in the research and deployment of situated and autonomic communications.

The consortium members are well-known institutions for large-scale network and software development projects, and have a proven track record in research and development. The expertise of the consortium covers all the needed background as described in Appendix A.

4 Relevance to the objectives of the FET activity objectives

The Internet reaches today a size and a complexity that its early designers never envisioned. From a few hundreds to now hundreds million machines, the usage of this network has drastically changed from sporadic static users to always connected mobile users, and from a centralized client-server design to largely distributed peer-to-peer applications. However during the course of its existence, the core design of the network layer of the Internet has followed the same basic networking principles, following a static and rigid pattern which has failed to offer innovative network services. To overcome the inherent static nature of the current Internet, many alternative architectures have been studied but none has succeeded to replace the existing scheme based on the thirty years old IP protocol.

A leading role for the European Union

The objective of the IST Call 4 in Situated and Autonomic Communications is to overcome the limitations of the current Internet design by promoting the development of radically new communication paradigms. The research community of the European Union (EU) must indeed put a lot of effort in this upcoming research field in order for the EU to play a leading role in this promising and highly innovative research area. In this integrated project proposal, we have regrouped a coherent team of leading European research institutes and international industrial partners, all actively involved in the development of novel networking systems and applications. The key driver of the creation of this consortium is the gathering of the complementary expertise of all partners: it results in a consistent and multi-disciplinary set of research and industrial entities which can contribute to bringing the EU to a leading role in research and deployment of situated and autonomic communications.

Building autonomic communications

The Autonomic Network Architecture (ANA) integrated project is a challenging attempt to provide and integrate a large set of pioneering and innovative approaches in the emerging area of autonomic communications. The main objective of ANA is to provide a new networking vision pervaded with self-* features, inherent *by-design* flexibility, embedded security, and integrated management and steering properties. In contrast to the current Internet, the ANA design will be fundamentally distributed in order to be naturally resistant to network failures and in order to evenly distribute the networking tasks throughout the peers of the network. Scalability is also a key feature in the design of ANA, since the goal is to demonstrate the autonomic properties of a virtual network of 10^5 network elements.

More precisely, the core of the ANA project is centered around self-* capabilities, which hold a central position in the FET-SAC work program. We indeed intend to specifically address the issues of self-management, self-optimization, self-monitoring, self-repair, and self-protection in a dedicated work package whose results will be continuously integrated as native features of our overall autonomic network architecture. Functional flexibility is also a central theme of ANA: it addresses the complexity issue raised by the FET-SAC initiative by providing a dynamic on-demand protocol stack that is not constrained by strict layering separations. The outcome, namely graceful evolvability, is a fundamental and innovative feature provided by ANA. Functional flexibility also leads to the ubiquitous composition of on-demand communication structures, in the sense that the network is able to provide in a distributed way any kind of peer-to-peer abstractions in order to fulfill the requirements of a set of communicating nodes.

5 Potential Impact

Network success stories, beside perhaps GSM, is mostly attributed to research in the US. This applies to the commercial sphere as well as network research. Initiatives have been launched to correct this bias (e.g. at the EU level the creation of the E-Next network of excellence and CoNext conference series). However, scientific and commercial advances do not emerge *automatically* from this, they have to be produced. ANA proposes a deliberate "the proof is in the pudding" approach where an autonomic networking system is the deliverable.

It is a generally accepted view among many networking researchers that the Internet architecture has reached its zenith. Due to its history as a simple interconnection tool where the few nodes could more or less easily be configured and managed by humans, the Internet had absorb many clever tricks to automate or at least concentrate management actions to a few interventions for end users. However, this approach is seeing its limit e.g., with hardwired addressing concepts that cannot be easily replaced. To some degree it can be possible to simulate autonomic behavior for some more years by adding more "tricks" to the old Internet technology, but in the long run it is necessary to rethink the whole architecture

How a new architecture should look like, however, is very much open. Internet like (open) networking has no closed theory available that would permit to derive and engineer an optimal architecture and to predict its properties. Being able to build, and validate, an actual system is the only way to proceed here. This is also the strong reason to use a testbed as a research vehicle in order to learn from the problems that occur during the building of a new generation network.

Building a new network is not an activity that a single research group can undertake. The problem set is too large and the dominance of the highly tuned Internet is too strong. This dominance has an impact in research publication channels which tend to be very conservative in assessing new ideas. With the FET call, there is a unique opportunity to provide a sufficiently substantial seed to make a first step into new networking territories, giving researchers in Europe a lead not only in concepts but also in actual autonomic networking systems. One should point out that, again, the research groups in the US already have attempted to enter theses areas, but so far these efforts have not lead to any system that could be demonstrated or that has been put into operation: contributions remained conceptual. With the FET-SAC framework, it becomes possible to open a window for system work large enough to succeed. Otherwise, only piecewise insights will be produced without a chance of validation and operation.

Renewing the network's core will only be the beginning of a cascade of follow-up "products". Once basic autonomicity is supported by the network, applications become possible that can concentrate on their specificity instead of having to spend most effort to work around limitations in the current model. The plethora of different overlays that have been proposed, not only for new applications (bittorrent, skype), but also for solving traditional network level tasks like routing (RON - resilient overlay network) better than the actual network, show that there is a huge potential for a richer network. We anticipate that a new network core will have a big impact on innovation in networked applications as well as networked services. By forcing this development to happen in Europe, we get a lead in the core domain of the information society - which is the network.

5.1 Update on potential impact

The goal of the project can be stated in one sentence: Demonstrate the feasibility of an autonomic network with the help of a running small-scale testbed within the project lifetime.

From the experience gathered during the first year of the project, we are very confident to have a strong impact not only in the research of autonomic networking principles, but also in providing a platform suitable to develop future networking concepts.

With regard to existing research programs in the US (Geni and FIND), the ANA project is perfectly in line with its research agenda and we are convinced to be able to influence research projects in these programs. Due to a strong link we established with Kansas University, we already share our research results with the US and work together on common design ideas as well as common testbed infrastructures.

Concerning impact in Europe, ANA was already able to influence multiple ad-joint projects:

1. One is a project on the federation of test networks (OneLab2) where ANA is used as the core technology to bridge clean slate networking approaches with the existing PlanetLab infrastructure.
2. Also an individual research project emerged form the activities within the ANA project; ResumeNet is building upon the core ideas of ANA's resilience and reliable networking Tasks.
3. Last not least there is the 4wards project that also implements future networking concepts. The steering board of 4ward asked for a workshop where the ANA core concepts should be introduced and explained; the project also considers the ANA core as one of the potential platforms for the research ideas developed in 4ward.

5.2 Contributions to standards

With its mission to take a fresh look at computer networking, standardization is not the main focus of this project. Moreover, the classical standardization bodies for the Internet or other specific technologies (wireless, phone, 3G etc) are focused on their field and would be the wrong place to address.

However, more research oriented forums like the IRTF, will be considered both for collecting views and requirements, but also to expose autonomic networking concepts especially when it comes to interworking aspects with (legacy) Internet technology.

Internal to the project, special care will be applied to terminology, interface descriptions and operation semantics to permit good interworking inside the project and to enable external parties to contribute research and implementation efforts.

5.3 Contribution to policy developments

Since Autonomic Communications is a new and promising research area, the ANA project and its future outcomes are expected to have a direct impact on research policies at various policy levels (as already stated in section 4). In particular, the technical demonstration activities of ANA, that is the development and deployment of a large-scale autonomic network, may influence decision-makers (government, academic and industry) in promoting projects related to situated and autonomic communications (SAC). The "proof of concept" promoted by ANA can indeed be the best advocate of the feasibility and viability of autonomic networking. That is, the main priority of the ANA consortium is to design an autonomic system which by itself will be a significant driving-force and promoter of situated and autonomic communications. We also plan to organise dissemination activities (e.g. workshops, demos) in order to promote autonomic networking, but one should note that our main focus remains on technical developments. We believe that a publicly funded design process and freely available ANA prototypes are the best way of gaining broad acceptance for critical networking infrastructures, for example by having a large research community scrutinize the results.

5.4 Risk assessment and related communication strategy

The ANA project aims at designing and developing innovative computer network systems. Therefore, we do not foresee any risk or harm to society/citizens.

6 Outline implementation plan for the full duration of the project

In practical terms, the ANA integrated project is globally organized in five work packages: four work packages (WP 1-4) are focused on architectural and technical developments and issues, and one work package (WP0, described in section 7) deals with the management and dissemination tasks of the project. While splitting the project into multiple work packages is essential in order to formally organize the various research activities, the organization of the ANA project has been designed to emphasize the relationships and the overlapping content of its technical work packages. The resulting practical organization of the project therefore stresses the many interactions that exist between the several research and technical areas of the different work packages. This overall project organization is illustrated by Figure 1 and is described as follows.

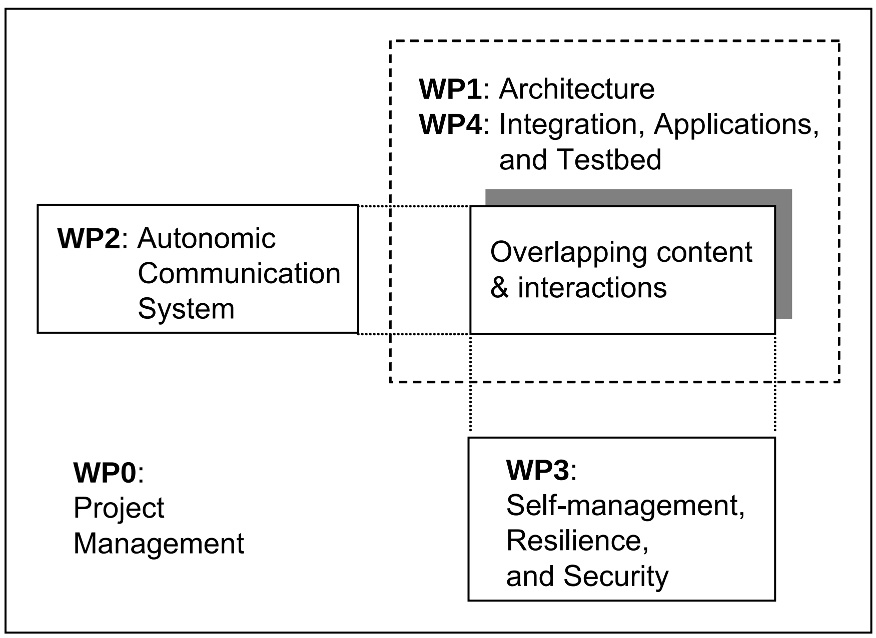


Figure 1 Project organization

Work package 1 (WP1) is focused on the overall architecture of the new autonomic network: it is the foundation and the main initial result of the ANA project. It specifically involves all the partners since we want to benefit from the different and complementary competences that form the ANA consortium. The main objective of WP1 is indeed to provide the basic ***blueprint*** for a new situated and autonomic network architecture by defining its elementary functional blocks (from forwarding abstraction to software entities), and by defining the (inter-) actions and semantics of these atomic elements.

Work package 1 is paralleled by work package 4 (WP4), which contains the implementation, deployment, evaluation, and testing activities of the project. The main objective of WP4 is the integration of the diverse developments of the technical work packages, namely work packages 2 and 3 defined below. In order to get a continuous practical feedback on the different parts of the architecture defined in WP1, WP4 will build and deploy a testbed which will gradually incorporate the functional blocks developed by WP2 and WP3. A systematic evaluation plan will be proposed to validate the operation of each functional block, to measure its performance, and to potentially trigger design modifications at the levels of WP1, WP2, and WP3. Finally, the benefits of the architecture will be highlighted by designing specific applications that will demonstrate the innovative features and design of ANA.

Work package 2, which focuses on the core developments of the networking functional blocks of the autonomic system, is strongly overlapping with work package 3 which contains the cross architecture aspects of monitoring and fault detection, network management, and resilience. This reflects the fact that all these aspects have to be included at all levels of the network architecture. The main focus of WP2 is to define the basic elements used to establish the path(s) between two or more communicating entities. Using traditional networking terminology, this includes naming, addressing and routing schemes for point-to-point, group, and overlay-like communications. Furthermore, this work package also deals with the self-association of nodes in an autonomic network, i.e. it addresses the key issue of situated context-aware networking. The goal here is to provide methods that lead to the autonomic on-demand integration of individual nodes as well as dynamic merging of whole networks. Finally, the essential two topics of service discover and communication structures customization are also covered by WP2.

While WP2 mainly deals with issues that are related to the *pure* networking side of ANA, work package 3 is focused on the different topics related to the control and steering of a running autonomic network. The goal of WP3 is indeed to develop the foundations required to perform autonomic network self-management, self-optimization, and resilience (fault-tolerance and recovery, self-protection and security, survivability, etc). These requirements are closely coupled with the developments carried out in WP2, and special care will be given to the close interactions that exist between these two work packages.

To achieve the ultimate objective of the ANA project, namely to design and build an autonomic network architecture, the technical organization of the project follows an incremental complexity scheme illustrated by Figure 2. The main purpose here is to clearly separate the conceptual aspect from the technical design.

The main objective of the first phase of the project, materialized by the activities of WP1, is thus to produce the conceptual specifications of the autonomic network architecture, learning from current and existing approaches (task 1.1) and driven by a clear definition of the requirements (task 1.2). This work package will then focus on the formal definition of the architecture (tasks 1.3 to 1.5), i.e. it will specify the desired features of ANA, but will be careful to not restrict its visions with technical and implementation constraints.

WP1 must study innovative networking concepts which are not restricted by the current technological limitations and shortcomings, and which take into account security concerns from the beginning.

The second level of complexity, i.e. design & conception, technical specifications, and prototyping of functional blocks, happens in both WP2 and WP3. Following the architectural principles defined in WP1, and building from their own conceptual specifications, the final outcome of these two strongly correlated work packages is the production/implementation of the atomic elements that form the autonomic network. These two work packages are therefore a combination of conceptual aspects and technical developments. Special care will thus be given in order to ensure that these two complementary aspects are sufficiently and adequately considered by each of the tasks of WP2 and WP3.

The highest level of technical considerations within the ANA project happens in WP4. The main task of this work package is to build and evaluate the different parts of the autonomic network architecture, and to integrate them in a large-scale (virtual) testbed. WP4 therefore deals with pragmatic issues such as testbed deployment, code integration, and the time consuming tasks of debugging of system-related issues. Moreover, specific autonomic applications that will demonstrate the innovative features of the ANA project are developed in WP4. An adaptation layer will also be developed in order to allow standard applications to access the ANA network without having to be modified.

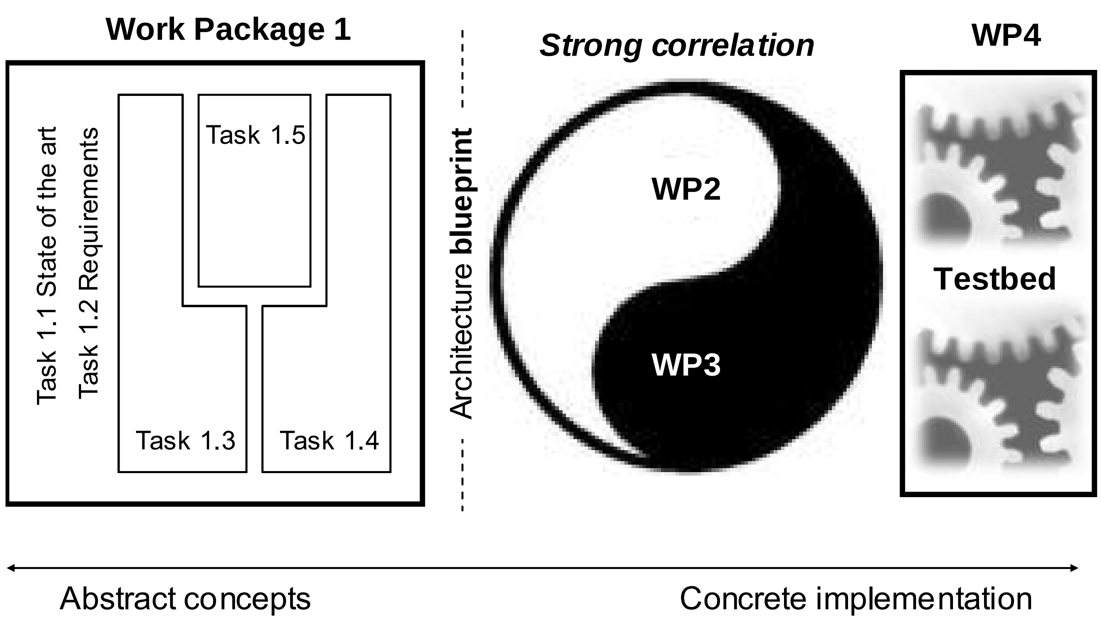


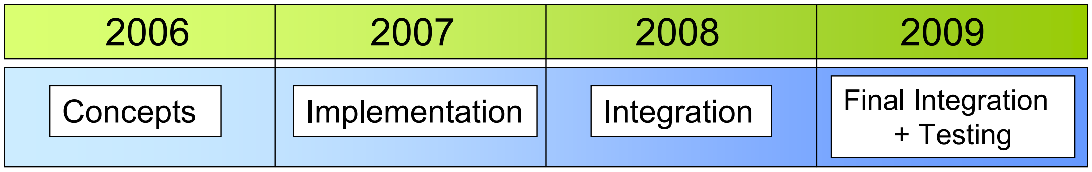
Figure 2. Overview of the technical complexity of the work packages

Each work package contributes to the definition and implementation of two-phase testbed that serve for the validation of the conceptual work. The goal of the first phase of the testbed is the elimination of manual management which is still required for the operation of even modest networks. This platform aims at demonstrating an **Autonomic Metropolitan-Scale LAN with Wireless Access (AMS-Net)**. This network relies on a classic fixed network core with simple wireless links at the edge. Using existing LAN technology for the physical layer (twisted pair Ethernet, WiFi), the task is to organize network functionality across this substrate in an autonomic way. The target size is of 10^5 network elements is already a very challenging size: current so-called "self-managed solutions" are based on auto-configuration inside pre-configured environments and scale to the order of some 10^2 elements. Networks with 10^3 to 10^4 nodes require careful planning, configuration and continuous monitoring, are restricted to fixed networks and typically have centralized management. No automatic solutions exist today for wireless multihop networks in this range, nor for hybrid networks. The same applies for the internetworking of any of these networks, where manual configuration or at least coordination among network partitions still is mandatory. The two central considerations are (a) robustness when running such a network in zero-intervention mode, and (b) extensibility and adaptiveness i.e., the ability to modulate network operations when introducing and imposing security policies or service quality. To cast it in technical terms: The task is to build a zero-intervention switched 10^5 network controlled by autonomic and extensible software. The testbed will also consider management aspects from a network provider's point of view.

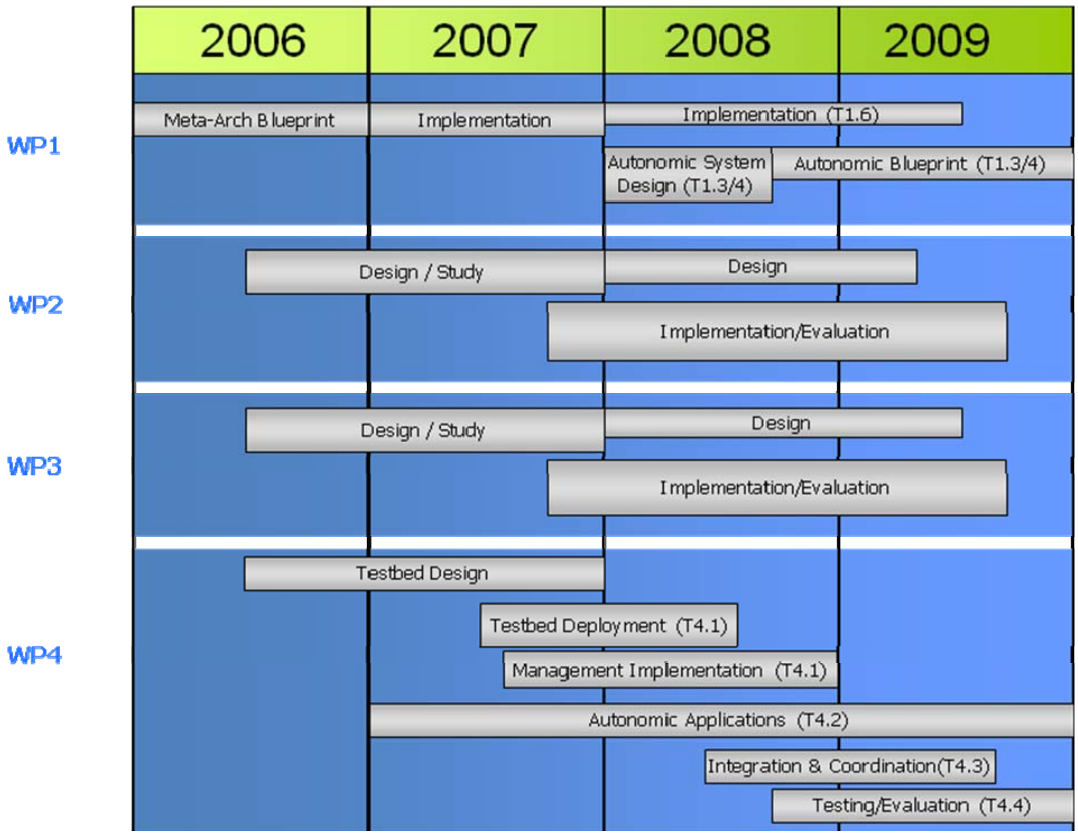
The second phase of the testbed is called **Autonomic (Wireless) Mix-and-Match-Mesh (M3-Net)**. It aims at autonomically establishing wireless hierarchies and performing networks integration. Wireless router clouds (consisting of devices in the class of access points, PDAs and PCs) form the intermediate layer of a network hierarchy that extends to low capability sensor nodes on one side and to long haul (fixed) network interconnects on the other. The two key considerations are (a) the integration of a variety of mobility management schemes and device classes and (b) predictive capabilities of the autonomic network which enables it to handle natural incidents (e.g., mobility) as well as malicious events (e.g., DoS) in a graceful way.

6.1 Updated Implementation Plan

In a short summary, one can distinguish four major steps or periods of the project. While the first year was mainly used to develop the basic concepts and abstractions of a novel, autonomic network architecture, the resources spend in the second year were to a larger extend devoted to implementation tasks as well as on the research of novel communication paradigms. In the remaining 2 years, we foresee to continue of course the implementation of the ANA core framework, but we will also transform the autonomic concepts produced in 2007 into ANA modules such that we can test them in real networking environments or integrate them with the bit and pieces developed in different tasks. The final year is then devoted to the final integration and the testing of the complete system.

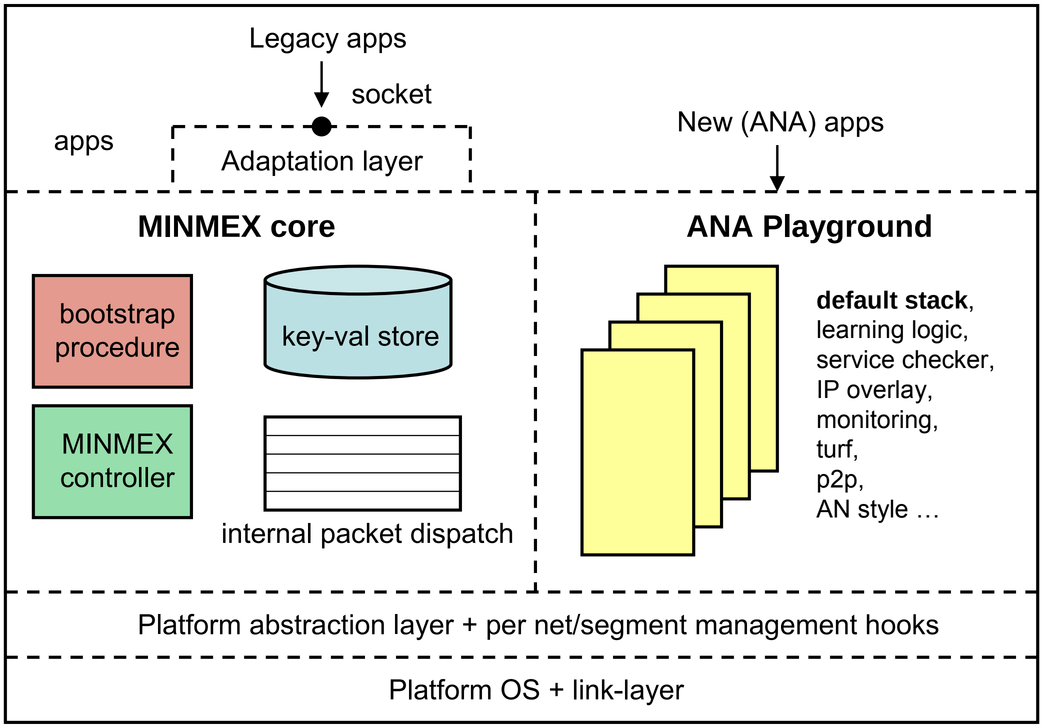


A more detailed view on the project unveils how the project moved the focus towards experiences and testing in the upcoming two years. Specifically in workpackage 2 and 3, the shift towards implementation and evaluation is nicely illustrated also in the upcoming 18 month plan. Note however that we still continue to perform analytical studies and design studies until the end of the project duration.

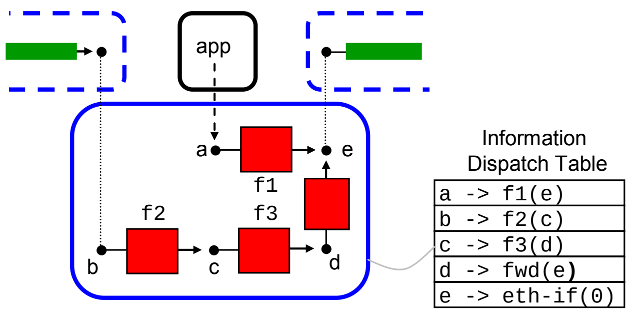


As mentioned before, the focus of the work performed in second year was on the development of the MinMex - the core of the ANA. The MinMex architecture was first described in Deliverable 1.3 of last year (also called the ANA Blueprint document) and has evolved since.

The figure below is a conceptual representation of an ANA node whose most prominent features are the **MINMEX** area (Minimal INfrastructure for Maximal EXtensibility) and the **Playground**. The MINMEX area defines the common denominator among ANA nodes, and MUST be present in all implementations. The Playground hosts the optional protocols that one is free to develop with the help of the functionalities provided by the MINMEX elements. The key components are the information dispatch framework, the key-value repository, a bootstrap procedure, and the MinMex controller.



The information dispatch framework is the most important feature in ANA. It enables the node to receive and dispatch packets or messages dynamically within a node. The dynamic rebinding of the packets is done with the help of Information Dispatch Points. Data packets are always sent to an IDP which is itself bound to a functional block (FB) or an information channel (IC) (at least conceptually). This approach provides ANA with powerful indirection capabilities that permit to seamlessly redirected packet flows according to network internal needs without the sender having to become aware of any change: it will still send data to the same (start) IDP.



The forwarding procedure inside ANA is illustrated in the Information Dispatch Table, which shows data being 1) received by a node compartment, 2) forwarded inside the node compartment and 3) forwarded to a distant node via an information channel. Data is received by IDP *b* which is bound to FB *f2* that has next-hop IDP *c*. Data dispatching carries on until reaching IDP *e* which calls a low-level function provided by the ANA Node abstraction layer that sends data via a network interface. Typically for link-layer forwarding, IDP *e* will store the information (e.g., MAC address) needed to reach the next hop network node. Note that the figure also provides an abstract representation of the forwarding table being used.

The Playground contains all the optional extensions of the base ANA node. This is where complex protocols and functions are implemented and where network-wide autonomicity is achieved. It is the area where variety will exist, perhaps even programmability in an active networking sense. Note that in the remainder of this section we intentionally avoid using the term "functional block" to refer to protocols and functions residing in the Playground: an FB may indeed contain multiple functions or a given functionality may be implemented in a distributed way by multiple FBs. We hence prefer to use a more neutral vocabulary.

In the second year, we also started to implement some first examples of networking applications in the ANA playground. Those were either developed in the context of WP1 and WP4, the core implementation task and the integration activities of WP4, or in the individual tasks of WP 2 and 3. Examples of the playground implementations are the Ethernet functional block, the virtual interface functional block (VLink), or the autonomic chat application.

Besides the ANA node architecture, the individual research groups worked on individual parts of the overall architecture or on generic concepts that will be integrated in the upcoming integrated prototype. Those concepts include work on:

- Routing
  We developed multiple routing schemes for intra-compartment as well as for inter-compartment routing. There are currently two inter-compartment routing schemes under development. One is using ideas of the TurfNet approach, the second one proposes some kind of yellow page routing scheme. Intra-compartment routing schemes are currently developed based on the Field-based routing approach. This approach allows for content-based routing and is implemented as a kind of publish-subscribe mechanism.
- Transport
  In this task, we revisited the fundamental trade-off between end- to-end and hop-by-hop transport control. The end-to-end principle has been one of the building blocks of the Internet; but in real-world wireless scenarios, end-to-end connectivity is often intermittent, limiting the performance of end-to-end transport protocols. We used a stochastic model that captures both the availability ratio of links and the duration of link disruptions to represent intermittent connectivity. We compared the performance of end-to-end and hop-by-hop transport over an intermittently-connected path. End-to-end, perhaps surprisingly, performed better than hop-by-hop transport under long disruption periods. We developed the spaced hop-by-hop policy which is found to dominate (in terms of delivery ratio) the end-to-end policy over the whole parameter range and the basic hop-by-hop policy over most of the relevant range.

  Practically, we developed and examined an alternative transport scheme to TCP or UDP: SAFT. SAFT stands for Store And Forward Transport. The idea is to implement a reliable transport mechanism that is based on hob-by-hop forwarding, but also supports end-to-end acknowledgements. SAFT has been implemented in a simulator and will be ported on the ANA platform later in the project.

- Monitoring
  Our Monitoring Framework focuses on two aspects of monitoring: the process of capturing or monitoring the node/network environment, and the process to share monitoring information with other instances. For both tasks, the implementation of the corresponding functional bricks is ongoing and first tests have been undertaken. The complete integration of all monitoring functionality is also foreseen for 2008.
- Optimization and Resilience
  The resilience framework specifies the principles and mechanisms necessary to provide fault-tolerance, recovery, security, and survivability. Its implementation has started and first experiences are expected for year 2008. The optimization task also made good progress (analytically as well as practically), specifically for a virtual coordinate system, also under development and available in 2008.

Details of the work performed can be found in the individual submitted deliverables.

6.A Activities

6.2 Research, technological development and innovation activities

As previously stated in section 2.3, the ANA project has two complementary objectives that iteratively provide feedback to each other. The scientific objective, i.e. *to identify fundamental autonomic networking principles*, is handled throughput the course of the project by a dedicated work package which purposely focuses on formal definitions and (partially) disregards technological aspects. The main goal is to avoid restricting the outcomes of the scientific objectives with low-level technical issues. In parallel, the technical objective of ANA, i.e. *to build an experimental autonomic network architecture and to demonstrate the feasibility of autonomic networking within the coming 4 years*, is also addressed via a specific work package which focuses on the integration of the networking functional blocks specified in the formal definition of the autonomic architecture. This activity results in the development and deployment of a large-scale testbed which will demonstrate the autonomic features of ANA, and provide experimental feedback to the architectural models. Moreover, the conceptual gap that exist between the scientific and technical activities of ANA is filled by two strongly correlated work packages which are responsible for *translating* the formal functional blocks into implementation-specific modules that can be integrated in the testbed. This organizational model will ensure that both the scientific and technological objectives of ANA are fulfilled throughout the duration of the project.

As stated in the previous section, the ANA project is composed of four technical work packages which are described in details in this section. Note that the project management work package (WP0) is defined in section 7, hence the description below considers WP1 to WP4.

6.2.1 Work Package 1: Architecture

Objectives

This work package involves all partners. It provide the basic 'blueprint' for a new situated and autonomic network architecture by defining functional blocks from forwarding abstraction to software entities and by defining their (inter-) actions and semantics.

This work package is the center piece of the integrated project and receives correspondingly a considerable amount of man power. Its first mission is to sketch the basic framework within 12 months for starting the work on the testbed. Once this initial conceptual work is done, this work package will continue to evaluate the results from the implementation phase (work packages 2 and 3), and from the trial testbed deployment phase lead by work package 4. If necessary, work package 1 will then rectify and complement the first network architecture. At the end of the 4 years, this work package will have produced an architectural framework that already has been validated through implementation (work packages 2 and 3) and testbed (work package 4) efforts, and which can demonstrate autonomic properties as also elaborated in work package 4.

Pragmatically, a network can be labeled *autonomic* when it provides inherent functionalities which lead to self-organisation, self-management, self-diagnoses, and self-repairs. These self-* features also imply that nodes can self-associate to the network without user intervention, and that applications self-discover available network services. The lessons learned from today’s networks (will be exhibited and analysed in task 1.1) have shown that this is impossible by means of a global and generic structure that “does it all”. On the other hand many of the above properties can be seen in environments where the semantics and the mechanisms of a network architecture have been localised and optimised to the requirements of its application domain. As a result, two main properties of the ANA architecture will be:

1) The ability of an ANA node to “virtualize its own network identity”. I.e. the ability of an ANA node to participate in multiple, potentially incompatible, network structures, whilst practicing different roles; this should happen with zero human intervention (with the possible exception of policies).

2) The ability of a set of ANA nodes to establish, localise and optimise a complete network environment taking into account coefficients such as resource availability, physical constraints and application domain requirements. This goes beyond the conventional problem of simply building an optimal mesh/topology in a given environment and crosses “vertically” all aspects of networking (naming, addressing, data transport, routing, etc).

To achieve the ambitious objectives of formally defining an autonomic network architecture, WP1 will be divided in five tasks which are strongly correlated.

Task 1.1 – State of the art (Task Leader: UBasel)

Previous attempts and related documents regarding the definition of (Internet-like) computer network architectures are identified and collected. The goal of this task is to provide a stable and comprehensive repository for base documents needed for our work. After an initial effort of merging the bibliographies from all partners to provide a global view, we will keep this repository up-to-date with all new publications in this field during the project's life time. The deliverable will be (a) a publicly available annotated list of all relevant documents, (b) a synthesis document that classifies and groups the various network architecture projects.

Task 1.2 – Requirements (Task Leader: UiO)

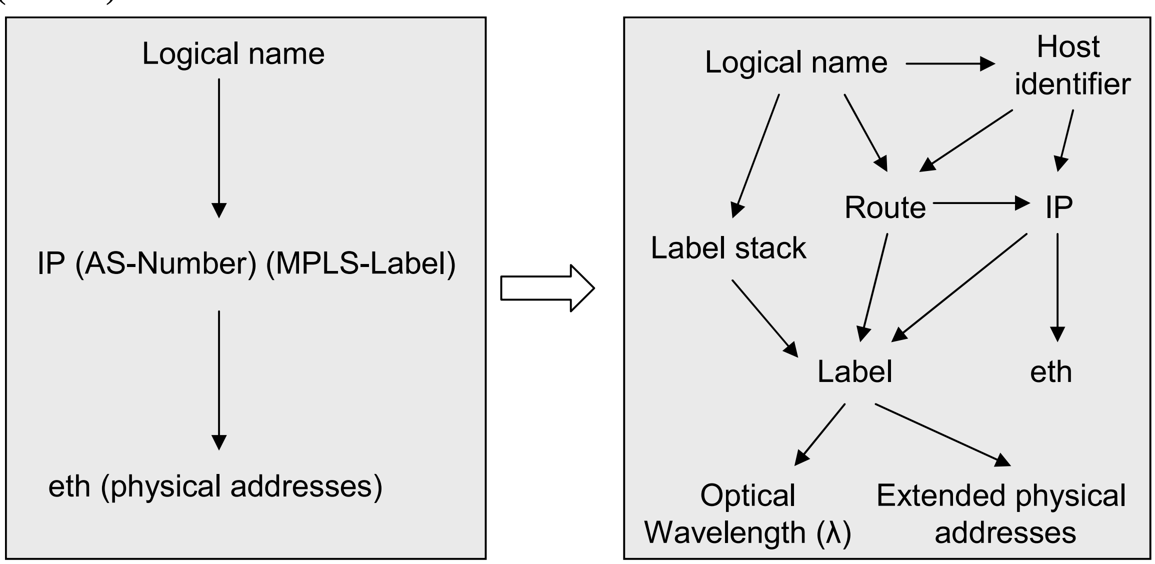
It is the aim of this task to identify the current and to predict the future requirements onto the next generation Internet seen from end-users, service providers, application developers, etc. point-of-view. This will be accomplished by literature studies (which will benefit from the work done in task 1.1) and will be based on the partners’ insight, both academic and industrial. It includes to study emerging services and applications over the Internet and end-user behaviour, e.g., by studying traces of advanced application like e-learning platforms. Furthermore, it requires to identify and understand the technology trends, like the trend towards mobile and ubiquitous devices.

The analysis of the information will result in a set of properties the ANA architecture has to provide and by this also to a blueprint for a benchmark of the architecture and the evaluation of ANA prototypes. The result of this task is a report.

Task 1.3 – Network abstractions and communication paradigms (Task Leader: NEC)

In order to meet the objectives discussed above there is an inherent need to re-examine and (wherever needed) re-define in a more general context the semantics of existing networking primitives and abstractions, as well as to propose and evaluate new ones. This involves basic primitives such as link, name, address as well as more high level abstractions and functions such as autonomous system, routing, software pipelining, overlay, and so forth. This will be the main focus of this task.

For example an important element to understand is the use of names, particularly addresses, and their scope. This issue is illustrated by Figure 3. In this subtask we will provide a spectrum of "name types" with different semantics ranging from pure local labels to global logical names. The key issue to clarify is the way how and when mappings occur between names. This involves the problem of late binding and corresponding look up services, as well as forwarding functionality based on name type and name value. The definition of name scopes (e.g. the boundaries formed by "turfs" or "virtual private networks" etc) is equally important. The activities in this subtask will contribute to the definition of a basic forwarding and demultiplexing shim for datagrams (task 1.4).



Names in classical (IP) networking

Naming flexibility in an autonomous network architecture

Figure 3. On the use of names and bindings

In another aspect it has been shown that given the requirements and data structures of specific classes of applications, it is possible to consider alternative information exchange paradigms that perform better (e.g. deploying multi-user information theory and network coding techniques under collaborative environments). It is among the aims of this task to define the abstractions and framework(s) (that will be later implemented within task 2.1) under which it will be possible to develop, embed and use new information exchange mechanisms.

A second, but no less important, goal in this task is to investigate and study ways of establishing the end-to-end communication between peers that are located in different network environments (compartments). This is challenging given the potential incompatibility between the localized semantics and the abstractions of the environments in which the peers reside. The goals here are:

1) Communication must be maintained under all circumstances (in a matter where information is forwarded whenever possible); with individual nodes making the decision on how and when to forward information when stable end-to-end paths do not exist.

2) Whenever feasible it should be possible to establish QoS-assured paths to applications that require it.

3) All management and control plane operations must be done in a survivable and secure manner, with security and authentication an integral part of the network and protocol architecture.

A third goal of this task is to investigate the architectural requirements and construct service provisioning frameworks essential in supporting end-to-end communication path establishment across multiple provider networks. The disparity in how provisioning is done in each domain, what services are provided, and how information is represented in each local domain presents great challenges. In addition, distributed system models for autonomic peers are to be designed to collectively provide the monitoring, provisioning, and adaptation techniques necessary to enable end-to-end QoS assurance across multiple provider domains.

Based on the outcomes of the work in this task, in later work packages we will develop and evaluate (by means of real world applications) the ANA node architecture.

Task 1.4 – Communication mechanisms (Task Leader: UBasel)

This task is about understanding the control actions on "network compartments", ranging from simple FIB configuration over stack reconfigurations to traffic indirection and filtering as well as complex security policies for virtual private networks. Unlike other tasks, we cannot give a list of subtasks to work on as this depends heavily on the actual abstractions proposed in task 1.3 and their properties.

The goal of this task is to produce a list of abstract interfaces that an actual implementation must provide in order to permit the use of an autonomic network's functionality. This is done by specifying (not implementing) the abstract APIs for the network abstractions from task 1.3 with a strong emphasis on system issues.

For example, a virtual link abstraction could be introduced inside and across compartments. Such virtual links would used to offer a uniform access to connectivity (instead of using an end node’s interface address as is currently the case in the Internet). To this end, mechanisms need to be provided to discover or specify, to create, to use and to release such virtual links. Related attributes can be carrier selection, QoS, disjoint routing paths for redundancy or simple precomputed metrics like the minimal number of hops. As virtual links can be stacked or extended, there is also need for a mechanism to express path composition. Paths can also contain protocol conversion or packet mangling functions like protocol boosters, whose actions must also be exposed to the client using the network. All this exemplifies the role of task 1.4 which for each communication abstraction proposed in task 1.3 must clarify its semantics and the interplay with the overall architecture. In this task we will also consider simulation studies in order to assess the scaling properties of communication abstractions and for identifying the boundaries for sustainable operation.

Moreover, the many interactions and potential conflicts between networking abstractions must be resolved here, and continuous feedback must be given to partners involved in task 1.3. In particular, interfaces have to be made extensible, but remain specific enough to be useful and amendable to further mapping to implementations in work package 2.

One concrete objective of this task is to define a forwarding shim, i.e. a demultiplexing layer that serves as a basic forwarding abstraction in the autonomic network. The goal is to extract the core forwarding control and data interface without restricting the design of virtual networks and their communication abstractions. We anticipate that the support for indirection control and late binding will be an important element. Another aspect to cover is the layering of the shim over legacy network for transition and testbed purposes.

Relating to task management activities over the whole project’s duration, this task 1.4 will shift from an initial activity for defining the first architecture blueprint in M12 to a continuous review of the implementation work in work packages 2 and 3 between M13 to M18. After having also accompanied the first phase of the testbed (AMS-Net) and analysed its results, task 1.4 will then revisit in totality the architecture and its communication mechanism to complement the architecture with respect to internetwork forming and to define the architecture’s second version that will be used for the extended testbed (M3-Net).

Task 1.5 – Information Flow Relationships and Requirements (Task Leader: Fokus)

Beside the basic data flows there is also a need to examine the flow of configuration information and monitoring data. This task examines the internal need of an autonomic network for various types of data items (routing, congestion control, debugging, self-monitoring etc) and interfaces to create and steer such internal information flows).

This task will identify requirement on a collaborative presentation of network information (subtask 1.5.1), define a general and extendable architecture for information distribution (subtask 1.5.2), and will define the necessary interfaces and items for information representation (subtask 1.5.3). The type of information that has to be considered defines the direction of information flows:

- Vertically,
    - edge-to-core directed information flows that make the core network aware of service and application related requirements, policies, etc. and thus support for context and situation aware network behaviour
    - core-to-edge directed information flows that provide a feed-back mechanism for applications and to convey data on network configurations and network states, technical requirements, etc.
- Horizontally directed flows inside the core network to maintain a decentralized representation of information item to make network compartments aware of global coordination and performance requirements, dynamic network topology and routing related information, congestion detection and prediction, propagated application related information, etc. This includes both intra-compartment flows and inter-compartment flows to for example support global Internet wide collaborative monitoring.

Subtask 1.5.1 - Requirements Collection

It is expected that the autonomic operation of the network will require new mechanisms to collect and distribute network control data, which should be integrated with the principle mechanisms of distributing user data. This subtask will consider the specific requirements of ANA in the flow of monitoring and configuration data in terms of which data items are required, which roles do compartments play in observing, controlling and organizing the network information, and on which time scales mechanisms should work.

Subtask 1.5.2 - Design of Information Flow Architecture

This subtask will design the information flow architecture for ANA by integrating the data into the compartments – giving integrated control and management plane that are not separated from the user plane. We propose to base this architecture on concepts for a fully distributed decentralized DNS combined with routing data to define and steer the flow of information between compartments. The support of observing, controlling and organizing network information will become special aspects/features of compartments.

Subtask 1.5.3 - Definition of Data Items and Interfaces

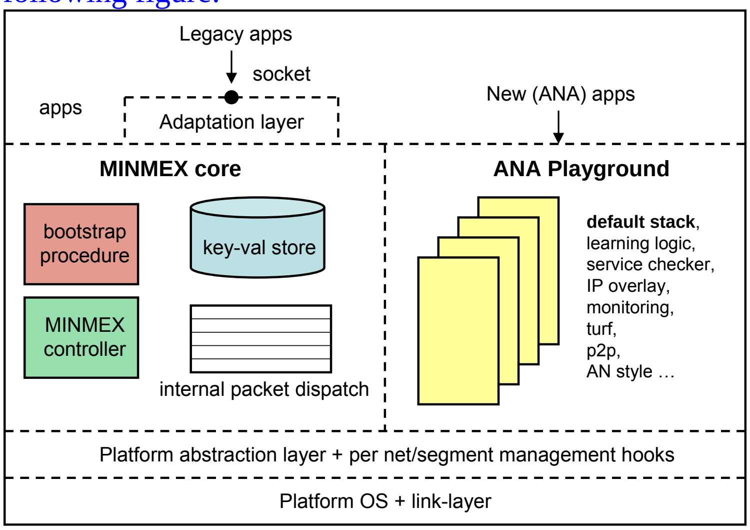
This subtask will finally define the specific data items and interfaces between compartments along the architecture defined in 1.5.2. It will also define scenarios for the usage and flow of data by interaction between compartments via their interfaces dedicated to support these information flows.

Task 1.6 – ANA Core Implementation (Task Leader: U Basel)

The main activity of this task is to continue the development of the ANA Core software. Based on the experience gained in 2007 during the implementation of the first prototype, a stable version of the software should be publicly released before July 2008. In addition, and based on the outcome of tasks 1.3 and 1.4, the existing software will be revised and extended in order to produce a second public stable release at the end of 2008. Note that this task requires close collaboration with Task 4.3 leading the integration of all the components being developed by other work packages.

Individual subtasks are:

- The development of the MinMex Core, including the elements illustrated in the following figure:



- We developed wrapper functions that allows development of code in:
  - Linux User Space
  - Linux Kernel Space
  - NS code

6.2.2 Work Package 2: Autonomic communication system

Objectives

Based on the communications abstractions defined in WP1, this Work Package defines the basic elements used to establish paths between two or more communicating entities. This includes naming, addressing and routing schemes for point-to-point, group and overlay-like communications. Furthermore, in the context of autonomic communications, it is important for individual network nodes to be able to automatically bootstrap (*self-associate*) in a new network context, or for the overall network to autonomously organise itself (*self-organise*). This WP thus deals with the issue of service discover, ad hoc integration of individual nodes as well as dynamic merging of whole networks (e.g., moving networks). Finally, this WP also investigates ways to dynamically compose the networking functions on an autonomic network node according to its network and communication context.

In order to support the *dynamic creation of communication paths* across self-organising networks, this WP will provide novel algorithms and protocols that support dynamic path lookup/setup operations. In traditional networks, this WP would encompass the lower layers of a node, i.e. routing, naming, and addressing. However, with the current approaches, these networking functions are isolated from one-another and they do not directly share information. From a node perspective, the creation of a communication path is a process, which mainly involves name lookup and link-layer address resolution. From a network perspective, routing is mostly a proactive activity, which establishes and maintains a global forwarding infrastructure, and requires that stable end-to-end paths exist in the network. Furthermore, node address assignment is a heavyweight process, which involves significant human resources. While all these networking functions are involved during the establishment of a path, the current IP-based architecture suffers from strict layering constraints, which introduce overhead and redundancy, and prevent upper layers from being able to adapt the environment and influence the behaviour of the lower layers. Furthermore, it has been shown that often there are significant benefits when the basic networking functions are more tightly related to one-another, for example in wireless ad hoc networks. One can indeed setup a path with a name instead of an IP address, and in the mean time, the name request can also gather enough information to perform the link-layer address resolution and to install appropriate forwarding entries in intermediate nodes of the network. Name resolution, routing, and link-layer address resolution are merged in a single operation. One can therefore find new approaches in order to overcome the historical constraints imposed by the IP-based architecture. These include novel routing and forwarding mechanisms that will enable resilient, survivable communication over mobile episodically connected paths for which communication is currently not possible.

Lastly, to address the issue of functional scaling as well as “forward compatibility”, it is important for an autonomic system to be flexibly extensible at run-time. This relies primarily on two mechanisms: first, the ability to dynamically load and install additional

functionality and second, a flexible mechanism to dynamically integrate the new functions with the existing network subsystem. Therefore, this WP will also investigate novel ways to achieve functional composition of individual communication systems. This will involve late binding techniques tailored towards individual communication paths.
As most of the work in this work package will provide functionalities that are fundamental for the basic and reliable operation of the ANA network, it is important to emphasize the prominent role of security. Although carrying out basic research on cryptography and other contextual areas is not in the scope of this project, special care will be taken to integrate and natively support such protection mechanisms in the ANA architecture (and therefore a parallel goal for all the tasks in this work package) in order to ensure that these functions are not subject to malicious exploitation or sabotaging.

Figure 4 illustrates how the different areas of research addressed by this Work Package relate and how they interact in the context of an overall autonomic network.

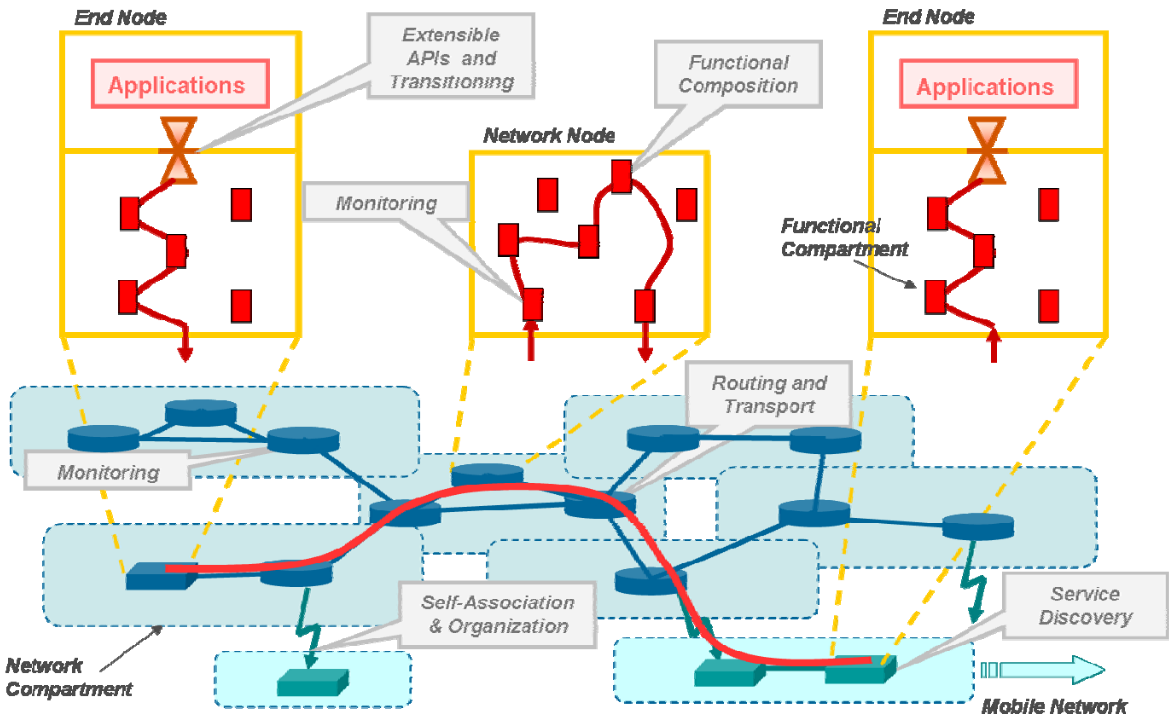


Figure 4. ANA Communication System

Work package description

This Work Package will develop the basic communication system of the autonomic network architecture proposed by this proposal.

The work will be divided into five closely connected tasks. These work areas will be described in more detail below. Figure 4 illustrates the different work areas and indicates how the results will contribute to the overall communication system.

The results of this Work Package will be both of conceptual as well as practical nature. During the first 18 month, the primary goal is to design the basic communication system for ANA. This involves studying and evaluating existing communication paradigms (not to abolish well-proven principles), but also to develop completely new methodologies and concepts for autonomic communication. The results of this conceptual work will be a draft design of the ANA communication system and a proof-of-concept demonstration of the basic concepts and mechanisms. After this, all the components of the communication system will be integrated into the Testbed, where they are systematically analysed. After this evaluation, the second cycle of design, development, verification and testing begins.

Task 2.1 – Routing and transport (Task Leader: UPMC)

This task focuses on new routing and data transport concepts that are suitable for autonomous and self-organising networks. It will develop innovative and efficient mechanisms to perform routing and data transport as an integrated service (albeit not in a monolithic way) across the overall communication system, and in environments for which current communication paradigms do not work well, if at all.

New types of communication abstractions (developed as part of the overall autonomic network architecture – see Task 1.3) will necessitate the introduction of new identifier spaces based on the semantics and the *mode* of communication: contact of an entity based on who it is (name), where it is (location), what it is (characteristics), and so on; this will be needed for users, applications, services, and nodes. Often, optimal routing will be based on different identifiers or even combinations of them (reflecting the need to move away from the opaqueness of layered models). This will result in autonomic binding facilities to resolve the identifiers to the correct communication entities and end-points.

The introduction of new communication abstractions will also necessitate the study of new types of routing and forwarding concepts for both network-wide paths (i.e. how is information routed throughout the local and global network) as well as node-local path lookups (i.e. how is information routed through a network node). No single routing scheme will be generic enough and at the same time optimal to account for all the various communication abstractions upon which routing is performed (note, for example that sensor networks use addressing, routing, and forwarding mechanisms incompatible with IP).. Instead, a framework that is able to fuse both routing-less approaches (such as proposed in network coding schemes) as well as to various routing schemes optimised for different abstractions is anticipated. This has the important result that the benefits of the IP hourglass are retained (a globally connected network), while individual nodes and compartments are able to use whatever identifiers, routing, and forwarding mechanisms are appropriate for their own needs. Autonomic switching nodes will enable this new framework to dynamically forward information in the appropriate manner. The dynamic and incremental integration of the various routing schemes within in a single framework is also expected to facilitate the evolution of the routing system.

Furthermore, as part of this framework, we will investigate new routing and forwarding mechanisms that permit resilient and survivable communication (Task 3.4) in challenged environments that do not permit routing convergence to conventional end-to-end paths (Task 1.3). Episodically connected links and mobility can subvert the stability needed for conventional routing algorithms. New paradigms and mechanisms will be developed that allow autonomic nodes to make forwarding decisions based on context and current conditions, and transfers information as far as possible, whenever possible and wherever possible [Sterbenz02]; note that directed diffusion [Intanagonwiwat00] and the delay-tolerant architecture[Fall03] are specialised point-solutions within this new paradigm.

The innovation here lays in the development of dynamic, context-aware, and adaptive routing and forwarding mechanisms for truly autonomous “compartments” (i.e., software components, network nodes, sub-networks), which are potentially owned and managed by independent administrations. The objectives of the routing scheme will be to achieve scalability, resilience (survivability, robustness and fault tolerance) as well as load balancing despite the high dynamicity (e.g. due to node or network mobility) and ad-hoc formation of the network. This will involve studying existing routing protocols and appropriate traffic management mechanisms that determine and exploit multiple paths, QoS-aware routing, forwarding abstractions, location-based and situation adaptive strategies as well as node-local functional composition techniques.

With respect to the end-to-end data transport, the objective is to reduce both the communication setup time and the overhead. One approach to improve the performance is by merging the service lookup and/or path setup procedure with other network operations. Security and management operations (WP4) can and must be natively integrated within the path setup procedure. As such, this task will investigate adequate measures to improve the overall performance of the communication system.

Task 2.2 – Functional Composition (Task Leader: ULancs)

From the abstractions and architecture defined in Tasks 1.3, 1.4 and partly 1.5, this task will focus on exploring new flexible ways of componentizing the communication functions, and develop a framework based on which these components can be integrated in a meaningful way, so as to dynamically compose a variety of network level services.

As the roles of network nodes are expected to vary over time in self-organizing network environments, the overall functionality provided by the service composite must be dynamically re-configurable in order to achieve autonomicity for the ANA node. New functions, protocols, and other software components can be incrementally and dynamically integrated, in order to provide the required functionality (for a given role of the node).

This task will start with a methodical analysis of the lessons learned from classical layered architectures and identify the cases where layering provides an acceptable solution, and where this model is insufficient - it is important to note that, the aim is not to completely abolish the useful abstractions provided by layered communication systems, but rather to implement them in a modular fashion. This analysis will enable us to explore the fundamental interactions and information that has to be shared in order to avoid instability or performance losses as a result of unexpected interaction between layers or components with contradictory goals. At the same time, we plan to examine various component-oriented paradigms and models from the literature (including micro-protocols [O'Malley90], flexible protocol stacks [Tschudin91], modular protocols [Feldmeier94], modular protocol stacks [Engler95], role-based architectures [Braden02], active component composition frameworks [Schmid05], and active middleware architectures [Coulson03]), and learn how to best exploit their semantics in our design (e.g. dynamic reconfiguration, late binding, function migration, etc).

We will explore, analyse, and implement the best alternatives for function composition along two directions, as well as explore the tradeoffs and relative benefit that dictate when each of these directions should be taken:

1) *Cross-layer and cross-over/underlay optimization and inter-layer control loops*: strict layering is inflexible and is known to be particularly problematic in wireless environments (e.g. [LaPorta04]). But in the cases where protocol layering *does* make sense, we will design and analyse cross layer mechanisms that provide *knobs and dials*: dials instrument the characteristics of lower layers and underlays in an upward direction, and knobs allow higher layers and overlays to influence the behavior of the underlying layers and components. Note that this can occur at all levels, for example between overlay and underlay, between application and transport layer, and between network layer and link layer. A critical aspect will not only be the interlayer API, but what can and should be exposed, how to search and redefine parameters, and what mechanisms to use across multiple layers (e.g. between the application and link layers).

2) *Modular network heap*: an alternative to a layer-based architecture is a flexible, reconfigurable, and searchable network heap (see refs above) as opposed to the traditional stack, whereby layers have been replaced by a pool of networking functions (components), which can interconnect in a dynamic ad-hoc and on-demand way in order to compose a required functionality. The "searchable" property will be the key to autonomicity, as componentization of the network heap will allow searching for the required functions as need arises. In cases where layering of functionality is considered best, the aim will be to relax the opaqueness and increase flexibility.

The resource discovery mechanisms that will be developed in Task 2.3 will provide ways of discovering new service components in the environment. The protocol lookup operation that will be developed in Task 2.4 will permit the creation and maintenance of dynamic paths between two or more components. Security features will be incorporated *inline* (as a native functionality), while monitoring capabilities and self-management functions will also be supported based on the results of WP4.

The deliverable for this task will be an analysis of alternative function composition mechanisms that provides insight as to their applicability, as well as a prototype implementation of the most promising in the ANA testbed.

Task 2.3 – Service discovery (Task Leader: NKUA)

This task focuses on the autonomic service discovery functionality of the network. More specifically, the goal of this task is to develop efficient algorithms for service discovery and advertisement, study the interaction of addressing, naming, routing and service discovery as well as to design a lightweight active platform for services and communities discovery.

When services are discovered on-demand, a process that is closely coupled with routing (task 2.1) will be employed; while service lookup requires routing to the service provider, path setup could be performed in parallel to service discovery. Service advertisement (or service information dissemination) can greatly facilitate the service discovery process. Since the information contained in the control data is needed in different parts of the network and at different levels of granularity, mechanisms such as filtering, diffusion, aggregation and other limited information dissemination strategies may be employed to reduce the associated overhead.

Service discovery in autonomic networks may be also facilitated through a joint routing and naming mechanism design, as for example encountered in Content Addressable approaches used in Peer to Peer networks. Service discovery is equivalent to finding content in an auto-organised network. The interaction of addressing, naming, routing and service discovery will be investigated and spontaneous service discovery mechanisms will be developed while Distributed Hash Table (DHT) abstractions and regular addressing structures will be considered for such designs.

An additional goal of this task is the design of a lightweight active platform for services and communities discovery. As network hosts frequently need to locate a system based on its role in a service or community rather than based on a well-known address, an additional challenge is that communities of machines need to cooperate together without having any a priori knowledge of their respective existence. Existing schemes often rely on the existence of some centralized server that swaps peers' addresses. Keeping these so-called "pong" servers scalable is a real challenge. The proposed lightweight active platform will help networks and application designers to introduce aggregators and caches of such pong servers transparently in the network.

In an autonomic environment a fundamental aspect of the service discovery process when first entering a network, is the ability to perform a zero-state configuration, that is, to be capable of coping with the lack of initial prior or manually specified state as well as the luck of preparation time to build up functionality (as happens when traversing from one network to another). In case of zero prior information or state such as when a node first bootstraps there is need to have a minimal resident algorithm (software) that tries to sense, test and/or interrogate its environment for a "first clue", and which will serve as the starting point for further discovery and loading of functionalities and self-association/configuration. One of the aims in this task will be the study and development of this resident bootstrap mechanism(s).

Another important aspect to be investigated is the design and construction of a unified service discovery system in multi-domain context. The emergence of diverse discovery mechanisms in recent years has created a heterogeneous service environment across the Internet where services and resources are published and discovered in many different ways (e.g. UPnP, Jini, SLP, Web service, etc.), none of which interoperates with others. In this project, we seek to bridge together many of the existing discovery mechanisms under a single unified discovery system. More specifically, our design goals include:

1) Common models for service advertisement and discovery overlaying multiple heterogeneous discovery systems.
2) Efficient information storage and retrieval architecture supporting inter-domain service and resource discovery.
3) Semantic representation of services and resources.

Task 2.4 – Self-Association and Self-organisation (Task Leader: NEC)

The traditional networking model, which relies on statically defined and globally agreed addressing and forwarding schemes, cannot be directly applied in the context of autonomic communication. A key characteristic of an autonomic network is its ability to *self-organise*. In addition individual networks nodes must be able configure themselves when joining the network. The process of automatically inserting a network node or a whole network, without manual configuration or centralised management is also referred to as *self-association*. This includes operations such as address allocation, routing configuration, service registration, etc.

This project also argues the need for network nodes to *self-configure* their pool of networking functions/components. This includes the ability of a node to add functionality incrementally (as need appears) and organise the available networking functions/components in a way that the node can operate in the given network environment/context.

These two steps (self-association and self-configuration) enable the autonomic insertion and participation of a node in a network (compartment). In other words, these steps enable a node to automatically load the relevant networking functions (e.g. network and routing protocols, authentication methods, etc.) and configure them accordingly after bootstrapping into a (new) network environment.

In order for an ANA node to load the required network functions for its association and organisation in the network, there is need for a uniform and generic service deployment mechanism that can support various (new) methods of obtaining a network function. As a result, one of the goals of this task will be to develop a simple, yet robust, mechanism that enables new network functions and service components to be loaded from the network environment and integrated into the node's component pool.

In spite of autonomic communication, networks grow, reduce, merge and split, often without any predictive assumptions or prior indication. In all these cases the network must self organise to smoothly accommodate the changes. However, such conditions have direct impact on the availability of services. In order to allow the network to control/steer its growth or mutation, without inadvertently impacting the service availability, optimizing self-organisation principles need to be studied. As a result, this task will develop autonomic cluster formation mechanisms and will investigate the impact of autonomicity on area coverage and node connectivity for dynamically changing network environments (varying mobility patterns).

This task is tightly coupled to the mechanisms developed and the research carried out in the other tasks of this work package. Routing capabilities and service discovery can be added on the fly when a node enters the network or when network partitions merge: synchronization with routing (Task 2.1) and service discovery (Task 2.3) must also take place. Furthermore, interactions with WP4 on self-management and resiliency are very important to address major issues such as authentication and self-protection to counterfeit malicious attacks (e.g. DoS).

Task 2.5 – Customization of communication structures (Task Leader: UiO)

The Internet is becoming increasingly populated by a variety of overlay and virtual networking schemes that aim at implementing, at the application layer, services that the core of Internet is currently not able to support per-se. Examples of these include peer-to-peer overlays, virtual private networks, grid overlays, and so on. The advantage of facilitating such virtual network overlays is that for particular applications, dedicated networks can be laid out over the Internet. However, these overlays are typically sub-optimal in terms of network topology and resource usage, because they are basically designed, implemented and configured independently and without support from the network layer. Furthermore, maintenance and support of these overlays is complex and expensive. Often, it even requires manual intervention, e.g., to install and place overlay nodes, and to assign different tasks/functions to overlay nodes.

The aim of this task is to retain the advantages of dedicated (overlay or virtual) networks by providing multiple customized communication structures to applications without the previously mentioned disadvantages of traditional overlays and virtual networks. Furthermore, these customized communication structures should exhibit the following properties:

- *On-demand creation and removal*: Customized communication structures are a natural vehicle for the implementation of distributed network services, such as distributed collaborative monitoring. In ANA such custom communication structures should be possible to establish on-demand, upon request and without any further manual preparation. In case a particular communication structure is no longer needed, it should resolve itself and release all resources it occupies.
- *Self-organization and self-management*: The creation and maintenance of customized communication structures should not necessitate manual intervention (apart from high level expression of policies probably). The configuration process itself must be flexible, such that it can adapt to the existing topology requirements, topology changes (i.e., topology aware), available resources (i.e., resource aware), and particular needs and goals of the application (i.e., context awareness). To achieve this goal the work in this task will build upon the mechanisms provided by other tasks in this work package (2.2, 2.3, 2.4).

- *Security*: Security is a fundamental aspect in such customized structures that should be strong self-protecting. This requires interaction with WP4 in defining built-in self-protection mechanisms as opposed on add-on patches as in current VPNs and overlays.

One of the main goals in this task will focus on the development of a flexible and extensible framework that can support the creation and management of multiple customized communications structures (compartments). Building on top of this framework we will then prototype various customized communication structures for well known common application domains.

An application that will demonstrate and evaluate the mechanisms to be developed in this task will be a service for global collaborative network monitoring which will be the subject of focus in Task 3.1. The challenge in that case will be to generate appropriate communication structures (compartment topologies and processing functions) which will enable the collection, filtering, aggregation and correlation of monitoring data at various appropriate places in the network. The selection of these locations will have to take into account the topology, available resources, physical environment constraints, the application context, and of course the security requirements.

Task 2.6 – Integrated Service Provisioning, Service Discovery & Routing (Task Leader: UWater)

Services and content are potentially provided by a large variety of entities in an ANA world. They will be made available, advertised and accessed efficiently as naturally supported by the ANA routing framework. The system can be perceived as a virtual distributed database, accessed by clients through service requests.
Two complementary levels are considered: *intra* and *inter*-compartment.
For *intra*-compartment, a content-based routing approach, in which routing decisions are driven by the content (i.e. services) requested by the communicating entities will be developed. Services will be published and pushed towards those entities who have subscribed to it. Requests can be based on simple attributes as well as regular expressions.
This infrastructure will span multiple heterogeneous compartments. Because compartments may have different service advertisement and discovery mechanisms, different service descriptions and different administrative policies, this task will also explore an *inter*-compartment service discovery architecture that allows service advertisement, discovery, and selection across compartments.

The challenge of content-based intra- and inter-compartment routing will be to formulate efficient and reliable means to determine routes, and to maintain the routing information over a highly dynamic, large-scale service infrastructure. Routing decisions will be determined by matching the attributes of the service to be discovered against predicates at content-aware nodes. Key issues that will be addressed in the development of the content-based inter-compartment communication infrastructures are efficiency, flexibility, robustness, and scalability

6.2.3 Work Package 3: Self-management, Resilience and Security

Objectives

The traditional network management model is orthogonal to the layered protocol stack structure. As such, the correct operation of the management system and the accuracy of the managed information rely on a mirror-image database of network state which is defined and standardized separately from the actual protocols and services being managed. This database is complex to maintain, and it is not straightforward to extract results from it that can be used as feedback to steer the network in an autonomic way.

The management of services, infrastructure, storage, configurations, traffic, etc, still relies on humans to extract relevant information from the database and take the appropriate management and control decisions. This empirical management style is one of the reasons why network management has achieved poor results in tasks such as automated troubleshooting and self-configuration.

Network security suffers from a similar problem: security is added to systems as an after-thought, and as such is not an integrated part of the service structure. This opens the door to security holes, since once the security add-on is compromised, the underlying non-secure system is easily exposed to attacks. Today to support the first generation of adaptive infrastructures, intelligent management and security tools use deductive reasoning to predict the effect of discrete changes (what-if modeling). Deductive modeling tools are only an intermediate step. They are not sophisticated enough to make decisions across a large number of elements and layers.

An autonomic network requires a completely new approach to network management and security, in which each functional building block inside each node comes with built-in self-management and self-resilience capabilities. In an autonomic network, malicious or erroneous entities could try and disturb an autonomic element in any possible way, and this element should recover and heal itself to continue providing the required service. In case of failures, alternative service blocks should replace the non-functioning ones in a reactive and unsupervised way. These localized self-* features must extend themselves to the granularity of a node, and then to the whole network in a fully decentralized way.

Environment monitoring is a first important building block for autonomic network components. Compared to other monitoring projects, our goal is to integrate the monitoring in the Autonomous Network Architecture itself. The challenging aspect of monitoring is related to the fact that a component can only monitor its local environment, when a lot of tasks need a more global view of the environment. The challenge here consists of merging information coming from different sources (local or distant) and to end in a global view of network. This problem is strategic in the context of global monitoring of the network as well as for self-protecting nodes, as anomalies (or changes) observed by an autonomic nodes might be coming from a problem not directly observable by the node.

To complement monitoring, inductive (i.e., predictive) modeling is a more elegant solution than deductive modeling. It requires a good understanding of the problem and a lot of monitored data. The big difference is that inductive modeling starts with the desired outcome, and the model returns the optimal configurations for all the elements of the infrastructure. Distributed artificial intelligence agents can monitor critical elements, or even learn which information is more relevant to monitor to achieve a given goal, and train themselves to make the right decisions in complex situations, such as failures or attacks. The inductive approach is "self-aware" in the sense that humans ultimately give up control to the network.

An autonomic network architecture must also be resilient to various failures and attacks. Knowing that the terminology used in this context is often overloaded and can be contentious, we will first define the more common terms used in the sequel.

A *fault* will refer to an inherent (material or design) problem in hardware or software. A *failure* is an event whereby an inherently faulty system/component stops working. The literature usually refers to *fault tolerance* as the ability of the system to recover from such failures, e.g. by providing redundant components. An alternative common wording would be *failure detection and recovery*.

Therefore in this proposal we will use the generic term *failure* to refer to the above-mentioned problems.

On the other hand, this project is also interested in problems caused by (deliberate) *attacks* on networks (or systems), and other challenging network conditions defined below.

A *(coordinated) attack* is a deliberate threat against the network resources, control protocols and software, including traffic attacks such as distributed denial of service (DDoS). Note that it is not necessarily easy to discriminate a traffic attack from a *traffic anomaly,* which is legitimate but unpredictable, such as flash crowds and extremely bursty high-bandwidth traffic such as distributed storage and Grid.

A *disaster* is a wide-scale destruction of an infrastructure. It may be natural but also the result of an attack.

Other impacts on the network include: (1) weakly and episodically connected paths primarily due to wireless links, (2) dynamic topologies and relationships due to the mobility of nodes, subnets, and compartments, and (3) high delay due to long paths (e.g., satellite links) or store-and-forward across episodically connected mobile nodes.

In this proposal we will use the generic term *resilience* to mean the ability of a system to recover normal operation in the face of *all* problems reported above, including failures, attacks, disasters, episodic connectivity, etc, and to do so as fast as possible to minimise the overall user QoS.

The term *survivability* [Sterbenz02] is used in a slightly more restricted meaning than resilience. It is the property of a network (or any system) to continue operating in the face of challenging environments (mobile, wireless, long latency) and to resist and recover autonomically from attacks and large-scale natural disasters, though not necessarily at the level one might wish for. The additional need to tolerate legitimate traffic anomalies drives the need for resilience. It is important to note that it is impossible to distinguish a sufficiently sophisticated DDoS attack from legitimate traffic, and thus the architecture and mechanisms to tolerate both are identical.

Work package description

The goal of this Work Package is to establish the new foundations necessary for autonomic network self-management and resilience, first of all at the granularity of protocol and service building blocks ("compartments"), then at the node level, and finally as the distributed autonomic management and protection of whole networks.

WP3 is divided into four closely related tasks described in more details below. Expected results are both conceptual and practical as they will be experimented over the testbeds. They will cover all the necessary aspects of management, such as monitoring, inductive learning from these data, various optimizations (for resilience, traffic balancing, etc) based on learning, failure detection and recovery, and resilience (e.g. intrusion or DoS attack detection).

Task 3.1 - Monitoring (Task Leader: ETHZ)

In this task we will design, implement and validate monitoring mechanisms and use cases. This task is composed of 4 subtasks.

- Implementation, integration and validation of a monitoring system (UIO, FOKUS, ULG, ETHZ):
- We have a set of independent monitoring bricks along the lines of our monitoring framework. These bricks will be integrated together and the functionality of this prototype will also evolve to include more advanced self-* features such as a self-adaptive MCIS, a virtual coordinate system (VC), adaptive traffic management, and mobility monitoring and prediction.

- *Adaptive Traffic Measurement (FOKUS):*
- In the first phase 3 initial bricks for realizing an adaptive monitoring scenario have been designed and implemented: Packet capturing, Adaptive Sampling and System Monitoring. In order to support an anomaly detection scenario with the adaptive monitoring compartment we will design and implement bricks for adaptive flow classification, aggregation and data analysis. Those bricks will be integrated into the adaptive monitoring compartment.

- *Wireless quality monitoring and mobility prediction (ETHZ):*
- We propose to develop a pattern matching-based scheme to predict (i) link quality variations and (ii) link residual lifetime. The idea is that this

mechanism does not require the use of any external hardware; it relies simply on monitoring Signal to Noise Ratio (SNR) as a quality measure. Nodes monitor and store the SNR of links to their neighbours in order to obtain a time series of SNR measurements. When a prediction on the future state of a link is required, a node looks for similar patterns to the current situation in the past (time series) using a cross-correlation function. The matches found are then used as a base for the prediction. Clearly, our method will take advantage of the occurrence and recurrence of patterns in human motion, which are reflected in SNR measures. It focuses only on the scale of links and as such is complementary to mobility prediction schemes working at the macroscopic level (i.e., AP occurrences) which target mobility prediction at a broader scale.

- *Use cases of monitoring services (UIO):*
- We want to investigate the integration of the monitoring framework to the services that wish to use them in some different use cases. Our goal is to come up with new types of monitoring services that scale better in functionality and efficiency than the tools of today. One concrete example is a Traffic monitoring and query framework: we will examine traffic load/type parameters (e.g., available bandwidth, packet loss) that can be maintained or calculated by nodes, and the associated overhead and resource requirements; and we will examine consequences of resource requirements for different node types, especially more constrained ones such as handheld devices and personal computers.

Task 3.2 - Self-awareness and optimization (Task Leader: ULg)

Three subtasks are identified on: (1) inductive learning, (2) distributed optimization, and (3) Concepts of self-awareness and optimization

Subtask 3.2.1 – Inductive learning
The subtask on Inductive learning refers to the analysis of collected network data to make them useful for self-management. There is a need to couple monitored data and AI techniques (inductive learning) to infer models of the network behaviour. Examples of models that could be learned automatically are: (1) a failures model characterizing the types and characteristics of resource failures, (2) a mobility model, characterizing the mobility patterns of mobile nodes [FLM04], and (3) a traffic model. In turn these models are helpful to take decision autonomously. For example, mobility prediction can improve QoS in a proactive way, failure prediction can be used to design more resilient routing schemes, and traffic prediction can be used to detect traffic anomalies or to optimize the network.

Subtask 3.2.2 – Distributed optimization
In the second subtask, we propose to focus on distributed optimization. In self-organized networks traffic engineering cannot fully rely on the existence of a central server that optimizes the network. Key-network nodes should perform this task independently of

each other based on the information available to them at a certain point in time. The subset of nodes (a community) involved in this task can be organised in a peer-to-peer (p2p) manner. Mechanisms that have been researched in the p2p community can be adapted to provide the right level of interaction and information propagation. In the context of the project a structured approach for the connection of the network nodes seems to be appropriate. For instance an approach as proposed by Omicron [DMS04] with a cluster and role-based scheme could be further developed to provide the infrastructure for the information propagation. Such a structured scheme has already built-in resilience features and does also take the capabilities and robustness of different nodes into account. Using the collected information the key-network nodes would take the decision for better optimisation based on rules applicable within a specific context. The advantage of this approach is that information could be propagated quickly within the system. Further, since decision would be taken in a distributed way the resilience and robustness of the system is ensured.

Subtask 3.2.3 – Concepts of self-awareness and optimization

In this task we explore concepts of game theory and reinforcement learning for achieving self-awareness and distributed optimization. The nature of network service and the Internet favors the modeling of network service as an open market where game theory could be applicable. The concept of game theory allows for rational selfish decision making at local level (i.e. for each user) without being aware of the global network state or assumptions of perfect information system. The overall system could be provably stable providing an effective mechanism for adjusting the dynamic equilibrium in place. In this task, we seek to provide such a system using service provisioning as an example. Another issue to be tackled is self-optimization through self-awareness. When dealing with complex problems, specific solutions may be devised that work well for specific set of scenarios. Due to the dynamicity of networks, it is impossible to capture all such scenarios at design time. By seeking concepts of reinforcement learning, we hope to establish an intelligent autonomic system that could reason about the performance of its operations and the appropriateness of its current decision logic. Using service provisioning as the context, we aim to design a system that can reason about its own QoS assurance schemes and the effectiveness of various heuristics in dealing with specific scenarios (as learned by the system over time) and be able to intelligently select the best fit at runtime.

Task 3.3 and Task 3.4 have been merged in Task 3.4 – Resilience

Task 3.4 – Resilience: Survivability and Security (Task Leader: ULancs)

This task will specify the architecture, mechanisms, and protocols that provide resilience and survivability of nodes, compartments, and the network as a whole. In this task we perceive and thus deal with security as an integral aspect of ensuring resilience, which falls within the main scientific objectives of this project. As pointed out earlier, in contrast with the current practice of realizing security in a reactive way, we abide to a more proactive philosophy. In ANA, security is considered both at the architectural level (embedded mechanisms) and therefore accounted in the various tasks of WP2, as well as the operational level, i.e. the way compartments and network (routing) topologies are (re)formed, react and optimize to counter organized attacks and other problems, the way information is exchanged, and the way events and other security-related data are logged and correlated. The latter aspect is dealt with in the task[1].

Subtask 3.4.1 - Resilience architecture and topology

In this subtask we will develop the network architecture and develop topologies that provide resilience and survivability. The main focus of this task will be in three areas:

First, a key aspect of the topology will be *geographic* and *policy-based* redundancy and diversity in network connectivity structures. Geographic redundancy is needed so that if a large part of the network is under physical attack alternate paths are possible that avoid the geographic region under attack. Conventional fault-tolerant alternate path routing does no good if the alternate paths are within the area under attack. This technique will be used both inter- and intra-compartment. Policy-based redundancy is needed in the case that an attack is against a particular administrative entity or compartment. This assures that diverse redundant inter-compartment paths can be established. This architecture and topology will be used, in part, to drive the autonomic routing algorithms (Task 2.1) as well as the self-organisation (Task 2.4).

Second, a resilient network requires autonomic nodes that are *dynamically programmable* and contain *storage* for the programs, as well as for data in transit that must be temporarily held due to episodic connectivity. These autonomic nodes will be *context aware* and able to react to dynamic conditions due to time-varying wireless channel conditions, mobility, and traffic anomalies. This will enable the proper routing and forwarding decisions (needed by autonomic routing in Task 2.1) as well as dynamically network re-optimisation (Task 3.2), as well as to provide resilience mechanisms to protect network resources and cross traffic from attacks and traffic anomalies.

Third, a resilient network requires secure and survivable control and management planes. This requires *separation* of data from control and management, with authentication and encryption of control and management traffic to resist eavesdropping, traffic analysis, and unauthorised insertion of network control messages.

This task thus provides the architectural building blocks for the resilience mechanisms and protocols that will allow the network to resist and recover from the impact of challenging conditions, attack, and traffic anomalies.

Subtask 3.4.2 - Resilience Mechanisms and Protocols

In this subtask we will use the architectural building blocks developed in Subtask 3.4.1 to investigate, develop, and analyse mechanisms and protocols to provide network

[1] It is worth noting that conducting basic research on security mechanisms per se (e.g. cryptosystems, coding algorithms, etc) is out of the scope of this project. We are instead focusing on the more practical aspect of how to incorporate or facilitate such mechanisms in ANA.

resilience. In particular, we will develop mechanisms for autonomic dynamically programmable nodes to protect network resources and application traffic in the following ways:

- Signaling to inform other nodes (intra-compartment) and compartments (inter-compartment) of attacks and traffic anomalies via secure control-plane messages so that they can protect themselves. This signaling will carry sufficient geographic and topology information so that the routing (Task 2.1) and re-optimization (Task 3.4) can resist and repair the network in an intelligent manner.
- Dynamic traffic engineering to throttle or drop flows that are causing difficulties to the network.

The result of this task will be a set of resilience mechanisms that will allow the network to resist and recover from challenging conditions, attack, and traffic anomalies. These mechanisms will be prototyped, tested, and re-evaluated on the testbed (WP4).

6.2.4 Work Package 4: Integration, applications, and testbed

Objectives

The fundamental goal of the ANA project is to build an autonomic network architecture whose autonomic capabilities could support network sizes of up to 10^5 nodes. While this objective is challenging in many aspects, one key issue is to be able to accurately validate and evaluate the many innovative functionalities provided by ANA at such a large scale. Clearly, deploying a testbed with 10^5 physical elements is a very ambitious goal in the realm of this project from a pragmatic point of view. Although the exact number might be difficult to achieve (at least at the beginning of the testbed deployment), the key aspect for the success of the project will be to argue, evaluate and <u>demonstrate</u> the scalability of the ANA to achieve the promised orders of magnitude. Furthermore, the ANA project plans to deal with this situation by means of virtual machines which can be installed on top of existing operating systems and computers (a more detailed description is given in section 8). It should be noted however that the longer term objective and dissemination strategy will aim to practically fulfill this goal.

The testbed development and deployment will consist of two phases. The goal of the first phase is to demonstrate the self-configuration, self-association and self-organization capabilities of individual nodes into a given network environment. The second phase, using insights from the first effort, will loosen the constraints and permit wired and (multi-hop) wireless heterogeneous devices to steer the organization and formation of the network in an autonomic way. Here the focus is on the optimization and adaptation aspects of ANA to form a resilient network and service environment and to validate the self-protection and security criteria set. This will involve the robust formation of localized compartments and the self-organization of these optimized network clusters into a global network. The reason for a two phase approach is that a robust architecture can only be developed incrementally and if its quality is validated in more than one situation. We also plan to build novel autonomic applications that will demonstrate the potential of the innovative features that will be provided by an ANA network. Since overlay construction (compartments) will be supported by the network in a native way, permitting the easy creation and deployment of highly customized virtual networks, we will concentrate on the development of highly distributed and dynamic applications.

Finally, while not an end in itself with regard to the project objectives, it is worth noting that such a testbed project could eventually attract a large number of researchers in the networking community if an appealing scientific objective is proposed (following the success of the *Planetlab* [PlanetLab] and the *Seti@Home* [Seti] projects). In task 0.2 (Dissemination), we therefore plan to actively work on an attractive framework in order to attract external participants (i.e. non-ANA partnership members) that will be willing to install ANA nodes on their computers. The goal is to benefit from the massive community of computer users (professionals or *enthusiastic amateurs*) in order to deploy and evaluate this challenging autonomic architecture. If the ANA network can provide enhanced services that are either not available or ill-provided in the current Internet, it will increasingly attract new users that will use it and drive the expansion in the size and broaden the scope of the testbed.

Work package description

Task 4.1 – Testbed and Tools (Task Leader: U Lanc)

This task aims to support the development and testing process within the project by providing a distributed set of ANA nodes over which partners can carry out experiments and system texting. This task is composed of 3 subtasks.

- *ANALab and ANA@Home System (UBASEL):*
- UBASEL will carry on the development of the ANALab software for monitoring and possibly configuring ANA nodes via a web-based interface. Part of this work will be done in collaboration with ULANC in order to produce the mechanisms for getting monitoring data and configuring ANA nodes remotely. The web-based interface will be developed by UBASEL while ULANC concentrates on the Nagios (http://www.nagios.org/) extension. UBASEL will also tightly integrate the ANALab and standard ANA Node software in order to produce a first prototype version of the ANA@Home software. The objective of ANA@Home is to enable remote researchers to join the ANA Testbed and participate in experiments and testing. In the first instance, this external access will be controlled and restricted.
- *ANALab Management System (ULANC):*
- ULANC will continue work on the Nagios based monitoring facility for the ANA Testbed and cooperate with UBASEL on enriching the ANALab testbed management suite. This effort will allow experiments to be remotely scheduled on the Testbed and any resulting logging information to be collected.
- *On-demand loading & configuring framework (ULG):*
- ULG will prototype an environment capable of hosting several bricks in a single user-level process. This environment should be capable of interpreting dependencies within a collection of bricks and automatically load and configure them, for example, as result of a compartment lookup in node compartment. (This work will pick up on work within task 2.4). We will also work on easing the support of information hook in ANA bricks.

Task 4.2 – ANA Demonstration and Visualisation (Task Leader: UiO)

The primary goal of task 4.2 “Demonstrations & Visualizations” is to create a demonstration that can be used to showcase the achievements of the various ANA tasks.

- *Demonstration and Visualisation (UIO):*
- The demonstration will be based on a physical demo unit, running an overlay/ P2P Video-on-Demand (VoD) streaming application developed in task 2.5. The application will integrate implemented ANA bricks in an overlay compartment.

The aim is to allow users to judge the perceptual QoS of the video stream by showing a streamed movie on a typical consumer set-top box. Two demonstration modes will be available. Firstly, an ANA testbed mode that demonstrates the ability of the system to work with the actual Internet and deal with the unpredictable nature of WAN traffic. Secondly, a simulation mode that gives a more controlled environment, where it is possible to demonstrate scenarios that cannot be realized on the ANA testbed, due to limited size, possible traffic types, and geographical node distribution. The system will offer node management functions and show a map of the network topology, with a visual display of the traffic patterns generated by both the data traffic and the monitoring framework. The task starts in month 36, and a delivery will be made in month 39, describing the planned design and detailed composition of the demo, based on the ANA functionality implemented at that point. The aim will be to deliver a code required to build the demo in month 48. The task will also provide a demo unit running on a set-top box/ laptop combination.

- *IP to ANA Adaptation Layer (UBASEL):*
- UBASEL will implement a first prototype of the IP to ANA adaptation layer. This will permit to use IP based applications over ANA by emulating the operation of "IP protocols" like DNS and ARP. The outcome is a software deliverable at M30 (will also include a report describing the final design).

Task 4.3 – ANA Integration (Task Leader: ETHZ)

The aim of this task is to pull together the work carried out in the other work packages and to evaluate the progress toward a usable ANA platform.

- *Overall Integration (UBASEL, ULG, NEC, ETHZ):*
- This task will re-evaluate the feasibility of building an autonomic ANA node based on the set of "bricks" currently being developed, with the aim of identifying:
  - Missing components
  - Missing interfaces, information elements, etc.

  The task will define how the various components can/ should work together to achieve autonomic behaviour in ANA nodes/ networks. Results should help steering the remaining developments in WP2 and WP3 and the integration. UBASEL will also contribute to the release of a coherent ANA Node by helping all brick developers to properly integrate their bricks into the existing software framework (i.e. use of appropriate development templates and functions) and ANA environment (i.e. correct use of the compartment API). A document, "Integration Guidelines" summarising lessons from this task the final ANA Distribution will be available in month 30.
- *Yellow-pages System (UBASEL)*
- This task focuses on the integration of the compartment "yellow-pages" system with all the existing compartments that will be developed in 2008. UBASEL will help developers to populate and use the yellow-pages system in order to ease inter-compartment communications.

- *Service Discovery (NKUA)*
- This task will develop a tool for the visualization of ANA specific service discovery algorithms with consideration for the ANA node environment to enable future integration.
- *Monitoring (FOKUS)*
- FOKUS is developing bricks that can be applied for various traffic monitoring tasks. The bricks provide functionality for packet capturing, flow classification, sampling, monitoring of system parameters and data aggregation. Integration work on these bricks will demonstrate the realisation of adaptive monitoring depending on situational parameters, for example, within an anomaly detection scenario.
- *Virtual Coordinate Monitoring (ULG)*
- The Virtual Coordinate brick implemented by ULG will be integrated with the other bricks of the monitoring framework (active probing, MCIS, orchestration). It will be used to provide accurate virtual coordinates to nodes, and thereby optimize the RTT measurements between any pair of nodes.
- *Functional Composition (ULANC)*
- This task builds on the work in task 2.2 on the functional composition framework; ULANC plans to spend some effort integrating this in the wider ANA software suite.
- *Core Implementation (ETHZ)*
- In addition to their coordinating role for the integration effort, ETHZ will continue to extend the core ANA implementation and assist partners in developing bricks for the ANA system.

Task 4.3 – ANA Integration (Task Leader: ETHZ)

This task addresses the testing needs of developers within tasks 4.2 and 4.3. Work will target testing of both the ANA application and the bricks developed to deliver the ANA platform.

- Application Testing (TA):
- We are interested to guarantee that current internet applications can expect to find usable the legacy communication interfaces. In that respect throughout these interoperability tests we would like to confirm the correctness of operation of the traditional socket APIs, and transport protocol operation. It is the intention that TA will conduct application testing in the later parts of the project which will suitably exercise and assess the ANA platform.
- Test Cases (FOKUS):
- This task will develop an ANA test environment which is based on the TTCN-3 (Testing and Test Control Notation) technology. It will offer selected test cases to test the conformance and interoperability of ANA bricks and applications. The test environment will contain:
  - Predefined TTCN-3 modules, which can be customized and extended for specific bricks and applications,
  - Adapters, which enable the automated execution of the tests, and
  - Guidelines for how to develop tests within the ANA testbed.

6.3 Demonstration activities

Spreading the ANA testbed

The demonstration activities of the ANA project are closely coupled with the work being produced by WP4, i.e. the integration and deployment of the ANA testbed. We indeed plan to continuously demonstrate the many outcomes of ANA via the large-scale public deployment of the testbed. The underlying idea is to follow the successful principles of scientific projects such as *Seti@Home*, *Folding@Home*, *PlanetLab*, etc, which have attracted a large amount of individual participants, universities, public entities, and companies, with an appealing scientific or humanitarian project. By building a public and opened testbed environment which will offer value-added services such as self-management and native customization (i.e. on-demand creation of peer-to-peer structures), we aim at attracting a large panel of potential participants that will help to increase the size of the ANA network and hence enhance its relevance. This continuous demonstration activity is specifically addressed within the ANA project via a dedicated amount of manpower (as specified in section 9.1). It will be carried out by most of the partners involved in WP4.

Building community networks with ANA

A second and more challenging goal is to reduce the gap that usually exists between the networking research community and the mass people which unfortunately often disregards network-related research projects which are perceived as *obscure experiments*. In the mean time, the mass people, especially the younger generations, are strongly attracted by the technological advances in networking. One striking example is the fast growing deployment of community-based networks such as ad hoc wireless mesh networks covering a city of a suburb. However, such deployments still require from their participants to have a non-negligible level of networking competences, which can potentially restrict the wide adoption of the related protocols and technologies. The consortium therefore plans to specifically demonstrate the suitability of ANA to build on-demand dynamic networks with no pre-requisite technical knowledge. The ultimate goal is to witness the wide adoption of ANA as the autonomic architecture used by the mass people. The demonstration of using ANA to build a wireless mesh network is specifically addressed by a dedicated amount of manpower. This activity will be mainly carried out by Telekom Austria which has a strong expertise in the deployment of wireless networks.

6.4 Training activities

Since ANA is a FET Integrated Project, we do not foresee any training activities during the course of the project. However, specific dissemination and exploitation activities are foreseen; see the following section for more details.

6.5 Management of the Consortium activities

Project Management

This activity will carry out the overall project management and coordination tasks. Overall management will be provided by the project coordinator, the work package leaders, the task leaders, and the project coordination committee (PCC). The project coordinator is responsible for representing the Project in relations with the Commission, for monitoring the overall performance of the Project, for coordinating the dissemination and exploitation of the project's results, for coordinating the production of the deliverables, for convening and chairing project meetings, organizing meetings with the Advisory Board and for assembling the management reports. Task leaders are responsible for the accomplishment of the technical objectives of their tasks, for coordinating the production of the deliverables, and for reporting to the project coordinator. The PCC is responsible for the taking of strategic technical decisions, for providing technical directions, for resolving problems, and for validating the achievement of milestones and project deliverables. Collaboration among the partners will be done through a secure web server, through email reflectors, through the exchange of papers and reports, and through regular meetings. It is expected to have two project meetings in each calendar year.

Exploitation and standardization plan

The long term success of this project depends heavily on the acceptance of the new network architecture. To achieve this acceptance, we define two major objectives:

- discuss and promote the design principles and architecture in the major standardization forums;
- provide an example implementation to the interested external partners and invite new partners to join the ANA testbed.

To discuss the novelties and advantages of the autonomic nature of ANA, we plan to present and discuss ANA in international standardization forums in the wireless community and the Internet standardization forums. Note that we are not yet looking for an international standard, but these conferences are a perfect discussion forum to promote our ideas.

We focus the exploitation efforts in the first 2 years in writing drafts for discussions within the IRTF and other wireless standardization conferences (ITU,…). Each of the participating partners (we chose specifically the coordinators and the industrial partners for this task) as well as the members of the advisory board will use their experience and connection network to disseminate the fundamental ideas to the corresponding forums.

6.B Plans

6.6 Plan for using and disseminating knowledge

Providing effective communication between the project and the potential user community is an integral and essential element of ANA. Indeed, ANA will inform and mobilize the user community from the early stages of the project through talks, presentations, email discussions, workshops and conferences. The first workshop is planned for the second year of the project and will focus on explaining the rationale of the ANA architecture and possibly on presenting some early results. A second workshop or conference is planned for the third/fourth year of the project and will focus on disseminating the achieved results and motivate interested users to actively participate in ANA. Both workshop and conference will probably be collocated with a major European Networking conference, such as CoNext (conference organized by E-Next). Besides the workshops there will also be a daily dissemination by the provision of an up to date and lively public website and email distribution lists. The project partners will also arrange to make presentations at two or three selected national research networking conferences.

In addition, ANA will liaise with the appropriate European and world-wide activities such as IST projects, NSF projects, NLANR, and IRTF, and in general all the major stakeholders of the area. In this context, the ANA consortium will establish a close collaboration with the other projects in the Situated and Autonomic Communication field. Yearly workshops and co-located project reviews will help to better integrate the results of the multiple research groups involved in the 4 projects. Specifically, we plan to work very closely with the HAGGLE projects on system and demonstration issues. Finally, to create a sustainable infrastructure, alternative funding opportunities will be explored at the European as well as at the national and regional level.

6.6 Gender Action Plan

This project is expected to be fully conform to the European policy of equal opportunities between women and men, as enshrined in the Treaty of the European Union. The participants conform to articles 2 and 3, and adhere to the Community tasks of eliminate inequalities and promote gender equality. Women’s participation in this project will be encouraged both as scientist/technologists and within the evaluation and implementation processes. All efforts will be undertaken that the number of women’s participation in technical and management work will be increased during the project in order to equal current disparities.

6.7 Raising public participation and awareness

As already stated in Section 6.2, the demonstration activities of the ANA project are closely coupled to the integration and public deployment of a large-scale testbed. Our goal is to develop *ANA@Home* (tentative name), a distributed open collaborative testbed/system similar to successful initiatives such as *SETI@Home* and *Folding@Home*. The main objectives are to attract external participants (e.g. individual participants, research groups, public entities, companies) and to disseminate ANA results. Outsiders from the ANA consortium should be willing to participate to *ANA@Home* because it offers high value-added services not available in the current Internet. A foremost example of such services is native communication customization, i.e. the on-demand creation of optimized peer-to-peer structures for dedicated purposes (e.g. group communications, network games, distributed computation, data mining, and database lookups). Moreover, specific autonomic applications that will demonstrate the innovative features of ANA will be designed.

Also as stated in Section 6.2, our goal is also to reduce the gap that usually exists between the networking research community and the mass people which unfortunately often disregards network-related research projects which are perceived as *obscure experiments*. One can note that a key feature of existing, successful, and widely used applications (ICQ, MSN Messenger, Skype) could be expressed as *communicate more*, or *meet (people)*. With ANA, we expect to extend this new “connected way of life” to *communicate on-demand*, or *meet your communication needs*. A success indicator would be to witness the adoption of ANA as the autonomic architecture used by the mass people for dedicated on-demand networking.

6.C Milestones

6.8 Major Milestones over full project duration

Work Package 1

M.1.1 Milestone (M12)

- First draft specifications of the ANA architecture.

M.1.2 Milestone (M30)

- Feedback from the experimental phase is received and analysed. Revisions and improvements for the second phase of the project are specified.

Work Package 2

M.2.1 Milestone (M12)

- Multiple drafts on the systems architecture (routing, composition framework, service discovery, self-* functionality).

M.2.2 Milestone (M18)

- Completion of initial prototypes and validation of individual functions/components, mechanisms, algorithms and architectures.
- Marks the beginning of the 1st Testbed Integration phase.

M.2.3 Milestone (M36)

- Completion of 2nd round of prototypes and evaluation of individual functions/components, algorithms and architectures (based on the revisited designs).
- Marks the beginning of the 2nd Testbed Integration phase.

Work Package 3

M.3.1. Milestone (M12)

- Initial drafts on the monitoring system, the optimization mechanisms and the security related technologies we plan to integrate in the system.

M.3.2 Milestone (M18)

- First version of the proposed mechanisms and architecture, validated by simulations or on some small local testbeds.
- Marks the beginning of the first testbed integration phase.

M.3.3 Milestone (M36)

- Based on the feedback from the first testbed, the second version of the WP3 related functionalities is completed.
- Marks the beginning of the 2^{nd} Testbed Integration phase.

Work Package 4

M.4.1 Milestone (M9)

- A first layout and technical specification of the testbed is provided.

M.4.2 Milestone (M18)

- A first version of the ANA testbed is implemented. It might not be complete, and will include the functional blocks available at month 18.

M.4.3 Milestone (M24)

- First version of the ANA testbed is fully operational and integrated.
- Marks the beginning of the first in-depth experimental phase. Feedback is returned at M30 to start second milestone of WP1.

M.4.4 Milestone (M36)

- Second testbed integration starts, based on new design from WP1 and on updated networking elements from WP2 and WP3.

M.4.5 Milestone (M42)

- Second version of the ANA testbed is fully operational and integrated.
- Marks the beginning of the second in-depth experimental phase. Final architecture and operational feedback are made available before M48.

7 Project Management

Responsibility for the administration and management of the project and its resources will rest with the Project Coordinator, Dr. May. Prof. Tschudin will serve as associate coordinator and take over all relevant tasks if Dr. May is unavailable.

The Coordinator will supervise the project by monitoring progress and performance; ensure the communication flow between the Partners by distributing information to the other Partners on the project status, on achievement of milestones and deliverables, and on overall administration and planning. He will be assisted by the scientists responsible for the Work Packages who will monitor on a regular basis the progress in their Work Package. Reports on this progress will be circulated within the consortium through a Project Newsletter assembled by the Coordinator. The purpose is to keep all Partners fully informed on all developments within the project, to strengthen the interactions between the Partners. The Coordinator will organize and manage the project meetings and coordinate the preparation of progress and management control reports, financial statements and audits as well as he will consolidate the project planning and budgetary overviews using the inputs from the Partners. Further responsibilities of the Project Coordinator will include the maintenance of close liaison with relevant stakeholders and the management of evaluation and dissemination activities. He will also be in charge of the communication with the Commission through the responsible scientific officer. Complete progress reports, including the activities during the project meetings, will be submitted to the commission every six months.

The Coordinator will be supported through dedicated and professional project management division at ETH Zurich that includes highly qualified business management personnel, accountants, lawyers, and individuals specialising in personnel and gender issues. Support is also given by Euresearch Zurich, a dedicated office in the central administration of ETH Zurich supporting researchers since the 4th framework programme.

7.1 Organizational Structure

Project operation will be carried out through the complementary activities of the following actors:

- **PCC**: **P**roject **C**o-ordination **C**ommittee **-** the PCC will perform the overall project control
- **PM**: **P**roject **M**anager - the PM will perform the technical, administrative and financial project management
- **WPLs**: **W**ork **P**ackage **L**eaders **-** the WPLs will organise the activities of individual partners' contributions on the WP level
- **TCC**: Technical Co-ordination Committee – the TCC will supervise and define of the overall technical architecture
- **AB**: **A**dvisory **B**oard - industrial research fellows and established international academic researchers independent of the consortium

7.2 Management and Decision Making Structures

7.2.1 Project Co-ordination Committee

The joint responsibility (both strategic and operational) for the overall project will be held in the Project Co-ordination Committee. The PCC will consist of one representative of each partner (normally the partners' project leader) and will be chaired by the Project Manager. The PCC's responsibilities will be:

- Make strategic and organizational decisions, and agree on objectives and timescales and the Implementation Plan,
- approve the Joint Budget,
- Establish objectives of the technical working groups and monitor their progress,
- Establish and control the detailed work programs,
- Co-ordinate progress, co-operation and inter-working between the Work Packages and the different activities,
- Review parties' resources,
- Discuss and approve solutions proposed by the Project Manager to problems that may arise
- Approve consensus reports and control Work Package Deliverables for the Commission,
- Validate the achievement of the Milestones and Project Deliverables
- make proposals to the Parties for the review and/or amendment of the terms of the Contract and this Consortium Agreement
- decide on service of notices on a Defaulting Party and to assign the Defaulting Party's tasks to specific entity(ies) (preferably chosen from the remaining Parties),
- agree upon the entering into the Contract and the Consortium Agreement of new Contractors
- decide upon the alteration of the Consortium Agreement, and
- decide upon the premature completion/ termination of the Project.
- make proposals to the Parties upon the premature completion/ termination of the Project.

At least two PCC meetings per year will be organised involving all partners, but unnecessary meetings will be avoided and PCC meetings can be called in association with Technical meetings. During these meetings each partner will present their contributions according to their objectives that are initially planned. Some intermediate meetings could be organised in case specific needs arise.

7.2.2 Project Co-ordinator

The Co-ordinator (through the Project Manager) is the single point of contact between the Commission and the Consortium.
Pursuant to the Contract, the Co-ordinator is responsible for the following tasks and functions

- Represent the Parties (however, not legally binding) in relations with the Commission and IST concertation mechanism, and report to the Commission.
- Overall management of the Project and chairing the Project Co-ordination Committee
- Preparation of the meetings and decisions of the Project Co-ordination Committee.
- Convene and chair project meetings including Project Co-ordination Committee meetings
- Timely collection and, with the support of the Project Co-ordination Committee, preparation of statements, including financial audit certificates, from the Parties for transmission to the Commission,
- Ensure prompt delivery of all hardware, software and data identified as deliverable items in the Contract or requested by the Commission for reviews and audits, including the results of the financial audits prepared by independent auditors.
- Enforce compliance to the project's quality plan

The Co-ordinator shall not be entitled to act or to make legally binding declarations on behalf of any other Party.

If one or more of the Parties is late in submitting of Project deliverables, the Co-ordinator may submit the other Parties' Project deliverables to the European Commission.
To the extent that serious concerns regarding the financial soundness of one or several Parties exist, the Co-ordinator has the authority to require the appropriate letter of comfort to prove that the corresponding Party is able to fulfil the financial obligations with regard to the Contract and this Consortium Agreement. Until this is provided, the Co-ordinator is entitled to refuse the disbursement of the financial contributions of the Commission to this Party.

7.2.3 Project Manager

The Project Manager is appointed by the *Project Co-ordinator*. It co-ordinates the activities of all *Parties* according to the Work Package plans and provides the *Commission* with managerial and financial information. In detail, the Project Manager will have the following responsibilities (for these tasks the Project Manager will be assisted by the members of the *Project Co-ordination Committee*):

- Disseminate *Commission* information to the *Parties*.
- Co-ordinate the actions for exploiting the *Knowledge*

- Co-ordinate and promote the dissemination of *Knowledge*
- Administer project resources and monitor project spending
- Co-ordinate the production of Project *Deliverables*
- Co-ordinate the preparation and submission of Project Reports to the Commission
- Ensure preparation of project reviews, organize the team of delegates to and participate in the reviews
- Organize and prepare technical audit presentations
- Monitor the overall performance of the project

7.2.4 Work Package Leaders

The Wok Package Leaders are appointed by the partners in the Consortium. The WPLs have to control and manage the technical progress achieved on the WP level. They are responsible for the performance of WPs and have to carry out the following tasks:

- Check the progress achieved within the respective WP
- Co-ordinate co-operation between partners within the WP
- Indicate, under serious circumstances, insufficient quality or unacceptable delays in the contribution of individual members
- Participate in Technical meetings
- Control the status of the Milestones and Deliverables within the WP
- Provide monthly WP control reports to the Project Manager
- Provide WP inputs to Annual Project Reports and to Technical Audit presentations
- Co-ordinate the production of external papers and publications in the WP's topics
- Control the work of Task Leaders

Task Leaders (TLs) are appointed by the WPLs. Their role is to co-ordinate the activities of their own task in the WP. They report periodically to the WPLs.

7.2.5 Technical Coordination Committee

The Technical Coordination Committee (TCC) is formed by the work package leaders of the 5 work packages. The TCC controls the synchronization and relationship of the individual work packages, defines the global system architecture, and coordinates the overall technical progress. The TCC reasonability is:

- Make strategic technical decisions and agree on technical objectives
- Establish objectives of the technical working groups and monitor their progress
- Co-ordinate progress, co-operation and inter-working between the WPs and the different activities
- Discuss and approve technical solutions proposed by the WPLs to problems that may arise
- Validate the achievement of the Milestones and Project Deliverables

7.2.6 Advisory Board

The members of the Advisory Board are appointed by the PCC. The role of the AB members is to provide advice and to evaluate the progress of the work done in the project. Specifically, we expect the following benefits of the AB:

- External review of the research and development efforts
- Advisory role during the design phases
- Provide support in the standardization process
- Support the efforts in exploitation, e.g., promote additional implementations in research laboratories or industry in general.
- Provide an external view on the project and its orientation

The PCC will schedule regular meetings with the AB at least one time per year. Additional meetings might be arranged during critical phases during the design or the re-design periods.

For better integration with the other projects of the same FP6 call, we propose to mutually integrate a representative from each project in the Advisory Boards.

7.2.7 Decision Process

In order to coordinate the work among the Partners, a ANA Project Coordination Committee (PCC) will be formed at the start-up project meeting. It will consist of the representatives (or their proxy) of the 12 participating groups and will be chaired by the Coordinator or his associate. The PCC will have two meetings annually at one of the participant institutions to discuss the progress, which will be evaluated on the basis of milestones and deliverables. Required modifications to the agreed time schedule and plan of work as well as timing of deliverables and milestones will be discussed, as will be the possibilities for technology transfer and application. It is expected that most decisions will be reached by consensus as there is a good working relationship between the Partners already, but if a formal vote is required then each PCC member will have a single vote and the Coordinator will have an additional casting vote in the event of a tie. The members of the PMC will stay in close contact, and if required additional meetings will be held. The participant reports and the minutes of the meetings will be compiled by the Coordinator and distributed to all Partners and the European Commission (EC).
During the course of the project, the external advisors agreed to act as advisors for the research and development efforts, especially in order to cope with the high level of risks involved in the project.
List of external advisors is foreseen.

At the start-up meeting, which will be held within one month after the formal project start, the PCC will decide on the precise content of the Consortium Agreement. This agreement will have its foundation in the model contract and will address all specific aspects of communication between Partners, availability of material within the project, protection of Intellectual Property Rights and dissemination of results. In particular it will also specify the exact roles and tasks of each Partner and the scheduling of the delivery of reports and other documents needed for project follow up and reporting to the EC.

The PCC will also oversee that national and European safety regulations are implemented. Particular attention will be paid to the official guidelines concerning genetically modified organisms. The PCC will also pay attention that competent professional advice and guidance is used for the communication of project results to the public.
The programme of the Project is divided into 5 Work Packages. For each WP, one of the Partners (WP1: U Basel; WP2 NEC, WP3: WP4:U Lanc) will function as responsible participant leading the work in this WP. Nominated leaders for each Work Package are responsible for specific coordination, planning, monitoring and reporting referring to that Work Package. The scientist responsible for each Work Package will be in charge of the communication between the groups in the Work Package and will report on its progress in the Project Newsletter. The Work Package leaders will also provide more detailed reports, which will be used by the Coordinator for the preparation of the official report for the EC at the dates indicated in the contract.

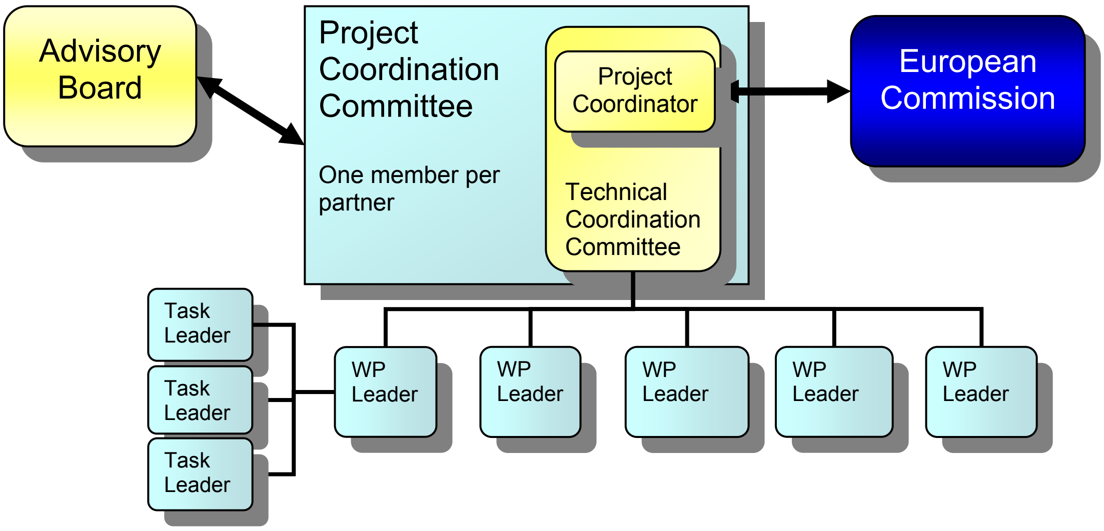


Figure 5. Organization Structure

7.3 Plans for Other Management Related Activities

7.3.1 Communication and Reporting

Information gathering and communication within the project will be ensured by:

- The establishment of a secure project web server;
- the establishment of a project repository (Subversion) to facilitate collaboration;
- the creation of a project mailing list;
- the exchange of internal technical papers and reports;

- notification of relevant new scientific publications and by the standard bodies;
- internal meetings, and reports from external meetings.

All technical documentation generated by the project should be exchangeable in electronic format, according to a set of guidelines to be agreed at project start-up. Compliance with these guidelines will be monitored by the Project Manager.

For regular internal discussions the following types of meetings are going to be held:

- PCC meetings
- Technical meetings (i.e., WP meetings, plenary meetings)
- Meetings with the Advisory Board

The meeting schedule depends on the project milestones and will be fixed at the project's kick-off meeting. It can only be changed under exceptional circumstances. Four project meetings are foreseen annually. The usage of video-conferencing will be encouraged for any other meetings in between the PCC and the Technical meetings.

Reporting throughout the project will be based on a systematic procedure to ensure the quality of the deliverables. The WPLs will provide templates for the contributions of the partners. These contributions will be validated by the WPLs and based on them each WPL will be responsible for reporting to the PCC for validation.

7.3.2 Quality Plan and Quality Assurance

The project will be carried out using the highest standards and procedures of workmanship, in terms of management, software and quality of deliverables, as befits a project at European level. The Consortium will follow formal quality procedures, using an agreed Quality Plan which meets the needs of all participants. In this document, the communication and reporting procedures, deliverable templates, project meeting draft agendas, meeting minute templates, and the actions that should be taken in case of conflicts are detailed. Moreover, it is the mandate of the Project Manager to ensure quality of the project's results as well as of its mechanisms and procedures. As part of the Quality Plan, Quality Assurance procedures are set up for monitoring the project throughout all project phases. Project monitoring will:

- intercept any mistake by means of implementing the Quality Assurance practices;
- identify and constantly manage the interfaces, monitor the progress of work, when it is necessary state who does what, give responsibilities and tasks;
- make objective documental evidences by the application of the Quality Plan.

The Quality Plan will be operated as a set of conformity rules and criteria. It will also include procedures for in-site inspection and expediting. In case of non-conformity the Plan will include both constructive measures for coping with specific help requests and correction measures for coping with any defaulting partner.

7.3.3 Exploitation and Dissemination Activities

Dissemination in this project will have an important and twofold role: dissemination of project results to industry in general and specifically companies interested in the addressed area, and dissemination of project results to the broader academic research community. Because this proposal is framed as an exploratory, long term project, the bulk of the results

will be made available to the general scientific community. The Partners consider scientific publications in international journals, as well as contributions to international meetings, as important instruments of exploitation. The standing of the Partners will attract new scientific activities to their laboratories. At the same time, by providing a successful scientific basis for industrial activities in the European Union, the laboratories will become more attractive to European industries for future co-operation.
A further activity for spreading the results among the research community and other potential stakeholders will be the organization of a public workshop within the second year of the Project to forge closer links between the participants, the industry and those who will ultimately be the recipients of the technology.

The workshop, taking the form of a 2-3 day international conference, will be organized by Partner 1 (Coordinator) in Zürich. The Partners of the Project, together with other suitable scientists (e.g., the members of the external advisory board), will form the scientific organizing committee. It is intended to establish a dedicated session with talks which might be of interest to SMEs. Besides the exchange of mere knowledge of the field of Autonomic Network Architecture, the conference will also have the goal of preparing a proposal for a NoE or an IP, depending on a possible call for such a topic. Thus, apart from the lectures, emphasis will be placed on discussions in planning groups.

To optimize the dissemination activities in our consortium, we’ll appoint a Dissemination Officer for coordinating all dissemination activities.

7.3.4 Intellectual Property and Knowledge Management

The project policy is to keep an eye on possible exploitation of the technologies emerging from the work that could lead to securing patents and then to seek for licenses. All Partners will sign beforehand a Consortium Agreement with an exploitation plan in order to guarantee correct handling of the possible commercial exploitation of the technology concept and will include conditions for confidentiality and regarding publications of results. The agreement will include that at the end of the project, potential objects of commercialization will be defined by the PCC and that a potential commercialization plan will be prepared. In cases where results indeed tend to lead to a commercial application, these results will be protected by patents, which will be negotiated among the Partners during the PCC meeting before publication of results. All exploitable results and all steps taken or required for exploitation of results will be communicated to the EC. The body of specialized lawyers of each of the institutions involved in the project will assist the securing of patents and the granting of licenses.
The PCC will ensure that all researchers involved in the project are well aware of the essential character of IPR protection for the success of the project. At the start-up Project Meeting, this issue will receive particular attention and all researchers will be urged to follow basic rules of confidentiality, proper documentation and certification of experimental results in laboratory notebooks.

8 DETAILED IMPLEMENTATION PLAN – MONTH 25-MONTH 42

8.1 General Description and Milestones

While the first 12 month of the project the consortium worked on the architecture and basic concepts of autonomic networking and the second year efforts focused on the development of an ANA core implementation, we will spend most efforts of the third year on the integration of the different research results, i.e., the integration of the functional blocks that were developed in year two or will be developed in 2008. Also, this year the autonomic features will come to the fore.

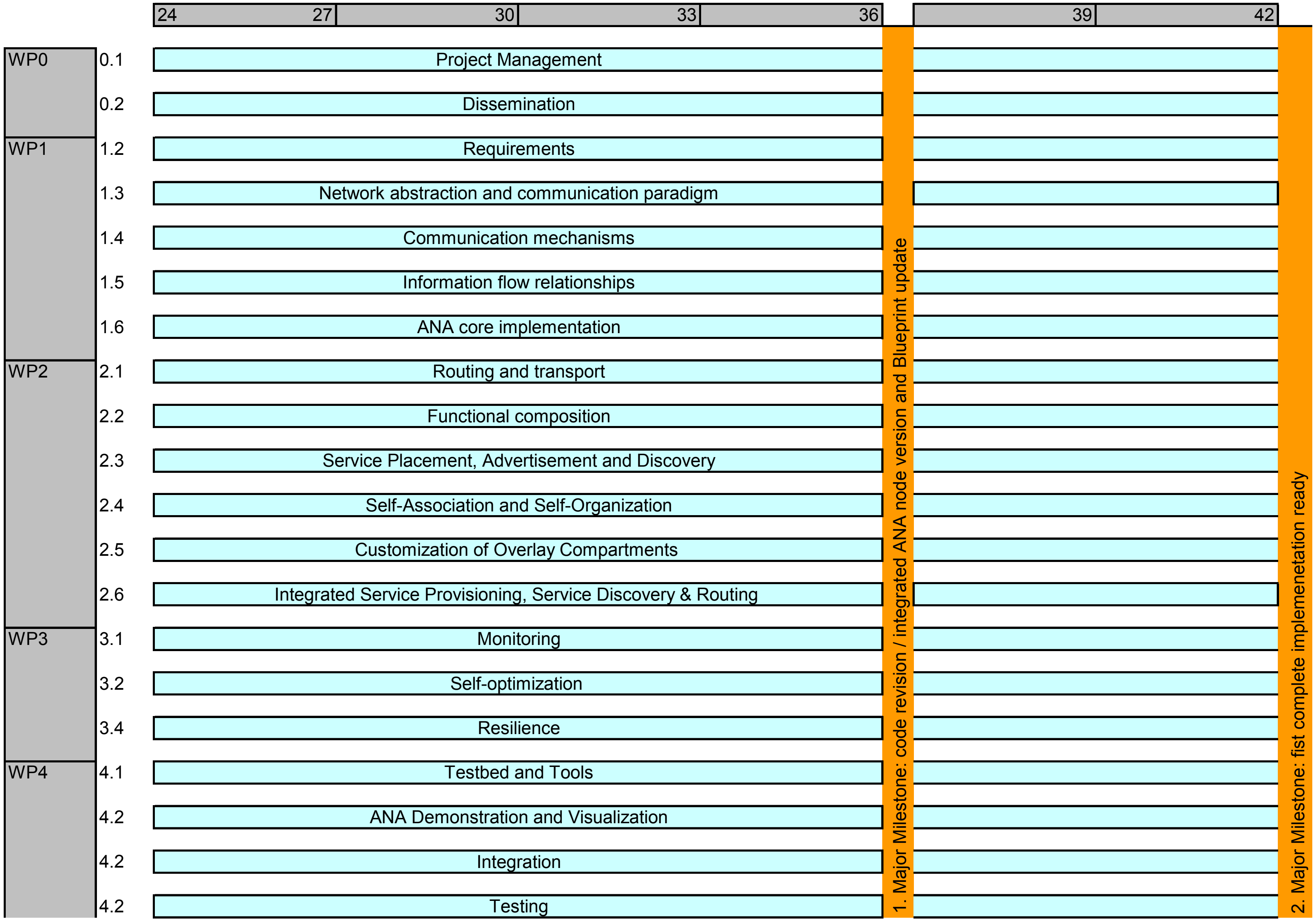
The two major milestones are hence the first integrated ANA prototype available at month 30 and the final integrated ANA node due at month 36. With the integration of the flow composition framework of Task 2.2, we will also be able to demonstrate the first autonomic functions eventually implemented in a running system.

As already observed in the first project year, there will be a strong interaction between the individual workpackages. In particular we expect the ANA core implementation having a major influence on the design and evaluation of the mechanisms that will be proposed in the workpackages 2 and 3. But also we foresee an important feedback from the testing and integration efforts of workpackage 4 on the node and network architecture.

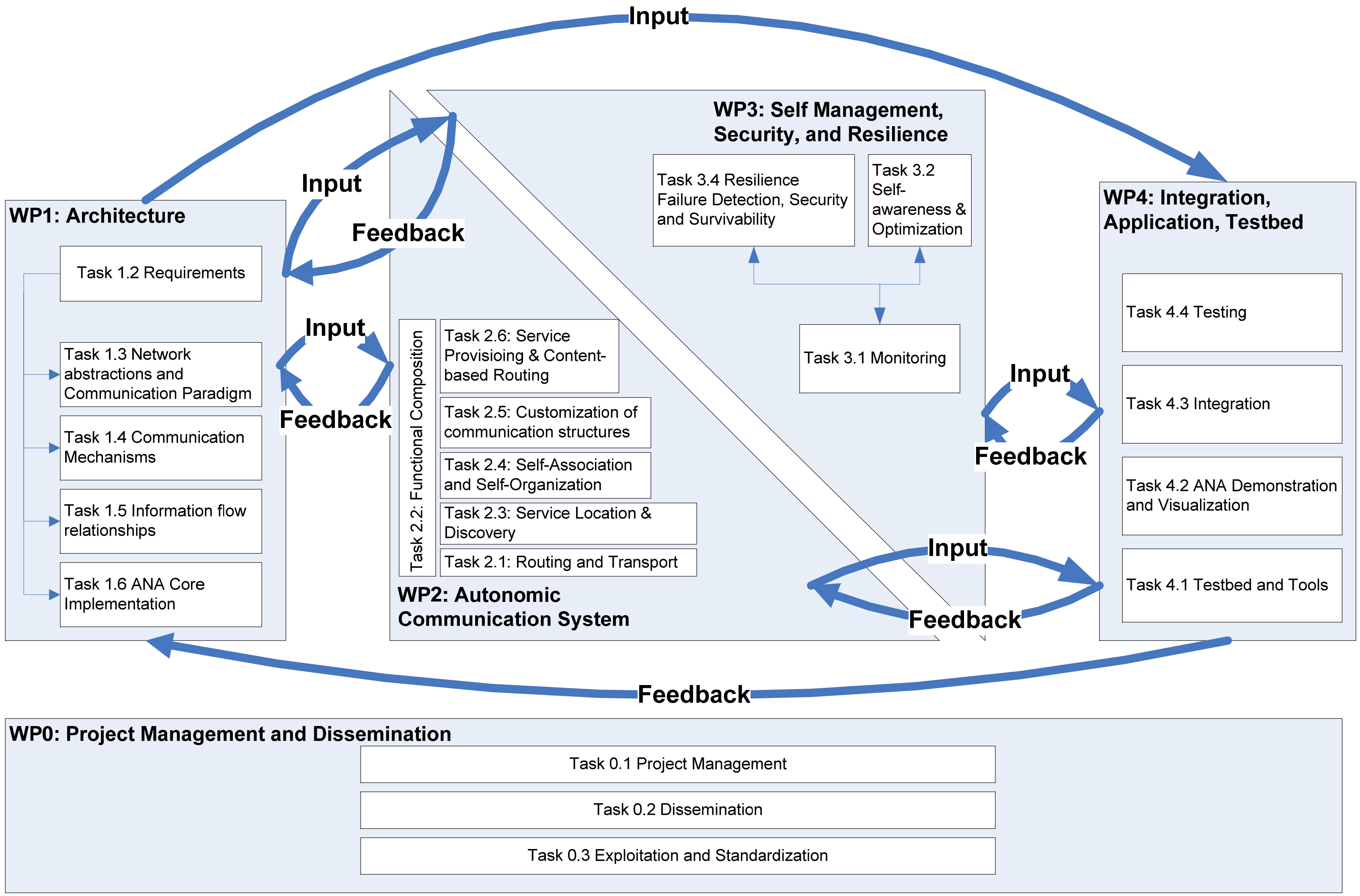
Workpackage 4, of course, will be very tightly coupled with the progress and outcome from Workpackage 1. The physical testbed will be deployed, representing some kind of "linkbed" that will be used later on to run large scale and distributed tests. Note also that individual testbeds are already available which will be integrated in the larger testbed in the course of year 2008.

Milestones are control points at which decisions are needed; for example concerning which of several technologies will be adopted / integrated as the basis for the next phase of the project.

8.2 Planning and Timetable



8.3 Graphical Presentation of Work Packages



8.4 Deliverables List

8.4.1 List of Deliverables

Del. no. [2]	Deliverable name	Lead participant	Estimated indicative PMs	Nature[3]	Dissemination level[4]	Delivery date
D.1.9 B	ANA Blueprint version 2, possibly including ABC-ANA work	NEC	5	R	PU	M36
D.1.9 B	Description of the low-level machinery of ANA	UBASEL	3	R	PU	M36
D.1.10	First public stable release of ANA Core software	ETHZ	5	R+P	PU	M30
D.1.11	Second public stable release of ANA Core software	UBASEL	5	P	PU	M36
D.2.9	Design and implementation of an intra-compartment routing scheme	ETHZ	8	P	PU	M30
D.2.10	Implementation of inter-compartment communication schemes	ETHZ	8	R	PU	M36
D.2.11	Implementation of a store-and-forward transport protocol for ANA	ETHZ	8	R	PU	M42
D.2.12	Integration of the Functional Composition Framework and Evaluation	ULANC	6	R	PU	M36
D.2.13	Service Discovery Phases: Conceptual Design and Evaluation	NKUA	10	R	PU	M36
D.2.14	Implementation of Self-Association and Self-Organization Mechanisms	NEC	14	R	PU	M36
D.2.15	Implementation and Integration of the proof-of-concept overlay streaming compartment	UIO	4	R	PU	M36
D.2.16	Final design, evaluation and prototype implementation of content-based routing mechanism	UPMC	18	R+P	PU	M36
D.3.7	The ANA monitoring architecture – version 2	UIO	26	R	PU	M36
D.3.8	Self-optimization mechanisms	ULG	22	R	PU	M36
D.3.9	Implementation of selected components of the failure detection and fault management	FOKUS	4	R	PU	M36
D.3.10	Measurement-based Resilience Mechanisms	ULANC	11	R	PU	M36
D.4.5	Extended Integrated Test-bed Infrastructure	ULANC	7	R	PU	M36
D.4.6	IP to ANA Adaptation Layer	UBASEL	5	R	PU	M30
D.4.7	Description of VoD demonstrator design and composition	UIO	7	R	PU	M39
D4.8	Integration Guidelines for the final ANA Distribution	ETHZ	20	R	PU	M36
D.4.9	Test Environment and Guidelines for ANA Application and Functional Block Tests	FOKUS	9	R	PU	M36

2 Deliverable numbers in order of delivery dates: D1 – Dn
3 Please indicate the nature of the deliverable using one of the following codes:
R = Report, **P** = Prototype, **D** = Demonstrator, **O** = Other
4 Please indicate the dissemination level using one of the following codes:
PU = Public
PP = Restricted to other programme participants (including the Commission Services).
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).

Note: this list only includes technical deliverables, i.e. deliverables related to management and dissemination activities are not included.

8.4.2 List of Milestones

No.	Deliverable name	Date due	Delivery date	Lead contractor
M.1.2	Feedback from the experimental phase is received and analyzed. Revisions and improvements for the second phase of the project are specified.	M30		UBASEL
M.2.3	Completion of 2nd round of prototypes and evaluation of individual functions/components, algorithms and architectures (based on the revisited designs).	M42		NEC
M2.4	Implementation of the different communication systems functions completed. Marks the beginning of the integration and evaluation phase of the ANA communication system	M36		NEC
M.3.3	First integrated implementation of a complete monitoring system, including MCIS and Coordinate System, IDE and parts (registries) of the CDE	M30		UIO
M.3.4	Four deliverables plus extended implementation, including a self-adaptive MCIS and adaptive traffic management.	M36		ULG
M3.5	Extended implementation, including the mobility monitoring, the self-organized coordinate system and measurement-based resilient mechanisms	M42		ETHZ
M.4.4	Second Testbed integration starts, based on new design from WP1 and on updated networking elements from WP2 and WP3.	M36		ULANC
M.4.5	Second version of the ANA Testbed is fully operational and integrated. Marks the beginning of the second in-depth experimental phase. Final architecture and operational feedback are made available before M48.	M42		ULANC

Work Package Descriptions (18 Month Plan)

Note: Throughout this section, the PM numbers given at the tasks level are indicative. That is, the ANA consortium may decide to change the affectations of PM among the tasks of a work package if relevant changes are envisioned during the course of the project.

8.5 Workpackage 0: Project Management & Dissemination

Workpackage number	0				Start date or starting event	M1
Workpackage title	Project management & dissemination				Leader	ETHZ
Participant id	1 ETHZ	2 UBASEL	3 NEC	4 ULANC	5 FOKUS	6 ULG
Person-months per participant:	9	2	3	0	0	0
Participant id	7 UPMC	8 NKUA	9 UIO	10 TA	11 UWATER	
Person-months per participant:	0	2	0	0	0	

8.5.1 Objectives

To ensure technical and administrative management of the project, interface with the IST program management with respect to reporting, and to collaborate with other IST projects within horizontal activities.

The objectives of the second task are to disseminate the results of the project, to motivate the critical mass of people to get involved in and benefit from ANA, and to explore the funding opportunities that will lead to a sustainable future for ANA.

8.5.2 Description of work

Task 0.1: Project Management **Task Leader: ETHZ**

[6PM: ETHZ 6]

This activity will carry out the overall project management and coordination tasks. Overall management will be provided by the project coordinator, the work package leaders, the task leaders, and the project coordination committee (PCC). The project coordinator is responsible for representing the Project in relations with the Commission, for monitoring the overall performance of the Project, for coordinating the dissemination and exploitation of the project's results, for coordinating the production of the deliverables, for convening and chairing project meetings, organizing meetings with the Advisory Board and for assembling the management reports. Task leaders are responsible for the accomplishment of the technical objectives of their tasks, for coordinating the production of the deliverables, and for reporting to the project coordinator. The PCC is responsible for the taking of strategic technical decisions, for providing technical directions, for resolving problems, and for validating the achievement of milestones and project deliverables. It is expected to have two project meetings in each calendar year.

Task 0.2 Dissemination **Task Leader: ETHZ**

[15PM: ETHZ 3, UBASEL 2, NEC 2, ULANC 2, NKUA 2, ULG 2, UWATER 2]

Providing effective communication between the project and the potential user community is an integral and essential element of ANA. Indeed, ANA will inform and mobilize the user community from the early stages of the project through talks, presentations, tutorials, workshops and conferences.

ANA will sponsor multiple workshops and conferences in 2008/2009. In these workshops, we will explain the rationale of the ANA architecture and will also presenting some early results. Besides the workshops there will also be dissemination by the provision of an up to date and lively public website and email distribution lists.

A very important mean to disseminate the ANA knowledge are tutorials and lectures. We already started this initiative (lectures in University of Basel and at ETH Zurich) and will continue and grow these lectures at the partner universities.
In addition, ANA will liaise with the appropriate European and world-wide activities such as IST projects, NSF projects, NLANR, and IRTF, and in general all the major stakeholders of the area. In this context, the ANA consortium will establish a close collaboration with the other projects in the Situated and Autonomic Communication field or projects funded in the 1 call of the 7th Framework program as well as the FIRE initiative. Yearly workshops and co-located project reviews will help to better integrate the results of the multiple research groups involved in the SAC/FET and FIRE

projects. Finally, to create a sustainable infrastructure, alternative funding opportunities will be explored at the European as well as at the national and regional level.

Task 0.3 Exploitation and Standardization **Task Leader: NEC**

[1PM: NEC 1]

To discuss the novelties and advantages of the autonomic nature of ANA, we plan to present and discuss ANA in international standardization forums in the wireless community and the Internet standardization forums. Note that we are not yet looking for an international standard, but these conferences are a perfect discussion forum to promote our ideas.

We focus the exploitation efforts in the last 2 years of the project in writing drafts for discussions within the IRTF and other wireless standardization conferences (ITU,…). Each of the participating partners (we chose specifically the coordinators and the industrial partners for this task) as well as the members of the advisory board will use their experience and connection network to disseminate the fundamental ideas to the corresponding forums.

8.5.3 Milestones and expected results

Successful coordination of the Project activities and smooth integration of the different WPs and of each participant contribution.

Successful dissemination and exploitation of results.

Successful workshop for establishment of conditions and networks for a larger Autonomic Network Architecture.

8.5.4 Deliverables

D.0.6 **Workshops**

D.0.7 **Overall project management**

8.6 Workpackage 1: Architecture

Workpackage number	1				Start date or starting event	M1
Workpackage title	Architecture				Leader	UBASEL
Participant id	1 ETHZ	2 UBASEL	3 NEC	4 ULANC	5 FOKUS	6 ULG
Person-months per participant:	8	10	4	0	0	4
Participant id	7 UPMC	8 NKUA	9 UIO	10 TA	11 UWATE R	
Person-months per participant:	0	0	0	0	0	

8.6.1 Objectives

This work package has focused in 2006 on the definition of the overall architecture for ANA: this has resulted in the release of version 1.0 of the "ANA Blueprint" in early 2007. After this release, the work package has focused in 2007 on the development of a first prototype implementation of the "ANA Core" software which provides the fundamental components of ANA. While this implementation has permitted to refine some architectural concepts of ANA (this lead to the release of a revised version 1.1 of the Blueprint in early 2008), it has above all permitted to refine the low-level "machinery" of the ANA Core and the API it provides for developing software for ANA. In addition, a first prototype of the "information flow framework" has also been developed and integrated into the ANA Core prototype.

Now halfway through the project and based on the experience gained during the prototyping phase, the focus of WP1 will concentrate on 1) the revision of the overall architecture and 2) the release of the 2nd generation of the ANA Core software which will embed the information flow framework. More precisely, the activitities of WP1 for the next 18 months are:

- To continue the development of the ANA Core software and release a 2nd generation of the software.
- To revise the conceptual specifications of ANA and release the 2nd version of the Blueprint.
- To refine and document the low-level machinery of the ANA Core software.
- To explore how the "ABC" framework of UWATER [Sigcomm'07] could be used to better formalize the specifications of the ANA architecture.

8.6.2 Description of work

For this work period (M25-M42), WP1 is sub-divided into three active tasks described in more details below. Note that compared to the previous work period, we have closed Task 1.5 which has released in 2007 the prototype implementation of the information flow framework. While this framework still needs to be properly integrated into the existing software, the overall integration activity is carried out by Task 4.3 and we hence decided to close Task 1.5 which focused on the design and prototyping of the framework.

Another change compared to the previous work period concerns Task 1.2. Since the release of deliverable D1.2 "ANA requirements" in November 2006, we've had no plan to revise the set of requirements for ANA. This task is hence put in standby (no PM allocated) but is not removed in case we identify new requirements that would require updating deliverable D1.2.

The three active tasks (1.3, 1.4, and 1.6) are summarized below.

Task 1.3: Network Abstractions and communication paradigm **Task Leader: NEC**
[7PM: UBASEL 2, NEC 3, ULG 2]

- Continuation from M24
- Task description:
  The main activity of this task is to revise/refine the overall ANA architecture based on the experience gained in 2007 with the development of the first "ANA Core" prototype and the development of various components such as the Node, Ethernet, and IP compartments, and the information flow framework. The revision of the architecture also implies identifying missing functionalities and necessary extensions of the ANA Core that need to be developed in 2008. The main outcome of this work will be the release of a second version of the ANA Blueprint at the end of 2008.
- In addition to this architectural work, WP1 will also study how the "ABC" framework developed by UWATE [Sigcomm'07] could be used to better formalise the specifications of the ANA architecture. One objective is to use this framework to specify the operation of the low-level machinery (i.e. packet forwarding and routing) of ANA. Note that this activity is purely exploratory.
- Deliverable:
  M36: D1.9 - **ANA Blueprint version 2, possibly including ABC-ANA work**

Task 1.4: Communication mechanisms **Task Leader: UBASEL**
[4PM: UBASEL 2, NEC 1, ULG 1]

- Continuation from M24
- Task description:
  The main activity of this task is to carry on the design and specifications of the low-level mechanisms and API of the ANA core software. The prototyping experience gained in 2007 will be used to refine some mechanisms such as for example the machinery used to manipulate IDPs. In addition, this task will also specify and design the mechanisms required by the new functionalities that could potentially be identified by Task 1.3.
- Deliverable:
  M36: D1.9 - **Description of the low-level machinery of ANA (part of the ANA Blueprint)**

Task 1.6: ANA Core Implementation **Task Leader: UBASEL**
[15PM: ETHZ 8, UBASEL 6, ULG 1]

- Continuation from M24
- Task description:
  The main activity of this task is to continue the development of the ANA Core software. Based on the experience gained in 2007 during the implementation of the first prototype, a stable version of the software should be publicly released before July 2008. In addition, and based on the outcome of tasks 1.3 and 1.4, the existing software will be revised and extended in order to produce a second public stable release at the end of 2008. Note that this task requires close collaboration with Task 4.3 leading the integration of all the components being developed by other work packages.

- Deliverables:
  M30: D1.10 (code) - First public stable release of ANA Core software. Editor.
  M36: D1.11 (code) - Second public stable release of ANA Core software. Editor.

8.6.3 Deliverables

D.1.9 **ANA Blueprint version 2, possibly including ABC-ANA work** (M36, NEC)

D.1.10 **First public stable release of ANA Core software** (M36, ETHZ)

D.1.11 **Second public stable release of ANA Core software. Editor** (M36, UBASEL)

8.7 Workpackage 2: Autonomic Communication System

Workpackage number	**2**			**Start date or starting event**		**M6**
Workpackage title	**Autonomic Communication System**				**Leader**	**NEC**
Participant id	**1 ETHZ**	**2 UBASEL**	**3 NEC**	**4 ULANC**	**5 FOKUS**	**6 ULG**
Person-months per participant:	**12**	**15**	**10**	**8**	**0**	**0**
Participant id	**7 UPMC**	**8 NKUA**	**9 UIO**	**10 TA**	**11 UWATER**	
Person-months per participant:	**14**	**18**	**6**	**0**	**18**	

8.7.1 Objectives

This Work Package focuses on the basic elements and mechanisms needed to establish paths between two or more communicating entities. This includes naming, addressing and routing schemes for point-to-point, group and overlay-like communications. In the context of autonomic communications, it is also important for individual network nodes to be able to autonomically bootstrap (*self-associate*) in a new network context, or for the overall network to autonomously organize and configure itself (*self-organize*). Therefore this WP deals with the issues of discovering service and network functionality, ad-hoc integration of individual nodes in the network as well as dynamic formation of complete networks (and this includes operations such as cloning and partitioning as well as merging of, potentially mobile, networks). At the same time a parallel goal of this WP is to investigate ways of facilitating such enriched and dynamic operations, within the network subsystem of the autonomic network node. Finally, security is a fundamental aspect of the basic ANA architecture, engineered in this WP.

In summary, the key objectives of this Work Package will be:

- Development of new routing and transport schemes based on the abstractions and primitives defined in Task 1.3. These schemes will be then employed for efficient, robust and case-optimal transportation of information in various network environments.
- Development of a flexible and dynamic function composition framework, which will serve as the basis for the ANA node network heap. This will replace the traditional static network stack, with a functionally enriched communication system.
- Design and implementation of service discovery and service advertisement mechanisms that will capitalize on the innovative schemes of ANA (mainly routing and self- abilities of the network). These mechanisms will allow the dynamic sensing of the network environment capabilities as well as the discovery of network functionalities.

- Study and development of self-association, self-configuration and self-organization functions that will enable ANA nodes to flexibly enter, establish and organize the network environment.
- Development of adequate functionality and appropriate interfaces for the dynamic customization of the network and communication structures in response to service and application requests (through application or service specific overlay compartments).
- Design and prototype a content-based routing approach, in which routing decisions are driven by the content (i.e. services) requested by the communicating entities. The challenge is to formulate efficient and reliable means to determine routes, and to maintain the routing information over a highly dynamic, large-scale service infrastructure.

8.7.2 Description of work

Based on the ANA blueprint, which defines the interfaces and the abstractions by means of which the ANA communications system will interact with the environment and with the applications, the task of this Work Package is to provide detailed specifications and prototype implementations of required functionalities or system components.

The overall objective of this Work Package is to develop the basic communication system of the proposed autonomic network architecture (ANA). The work will be divided into six closely connected tasks, which are described in more detail below.

The outcome of this work will be both of conceptual as well as practical nature. During next 18 months (M25-M42), the primary goal is to finalize the design and development of the basic functions of the ANA communication system and their evaluation.

In the final 6 month of the planning period (M37-M42), the work in the various tasks is expected to focus on the integration of the individual communication system functionalities into the overall ANA prototype system. After the successful integration, the evaluation of the individual system components as well as the overall ANA system will be carried over the Testbed (Milestone M.4.1) as part of the WP4 activities. Based on these finding, the individual system components will be evolved and a second cycle of (re-)design, development, and evaluation/testing will be carried out.

Task 2.1: Routing and transport **Task Leader: ETHZ**

[24PM: ETHZ 12, UBASEL 9, NEC 3]

- Continuation from M24
- Task description:
  Overall there are three goals in this task. The first objective is to progress the work on field-based routing (FBR) and store-and-forward packet transport (SAFT). While in the past, the focus was on theoretical examinations, the goal of the upcoming 18 month will be to implement the two concepts. The implementation of FBR is expected to be ready in M30, while for SAFT a prototype implementation is expected by M42.
  The second objective is to progress the ongoing design and development work on overlay-based inter-compartment communication schemes. Services joining this global compartment will be identified in the global network with unique flat identifiers, which precludes the need for explicit management of the identifier space and therefore facilities its deployment in an autonomic environment. Service resolution will be carried out via consecutive resolution steps inside the interlinked compartments, which enables end-to-

end communication despite the heterogeneity of the various underlay compartments. Finally, the third goal is to design and implement an inter-compartment routing scheme based on regular expressions for "encoding namespaces". Beside the development of the routing protocol itself, this activity will include the design and development of suitable forwarding mechanisms.

- Deliverable:
  M30, D.2.9 – **Design and implementation of an intra-compartment routing scheme.** This is a software deliverable.
  M36, D.2.10 – **Implementation of inter-compartment communication schemes.** This is a software deliverable.
  M42, D.2.11 – **Implementation of a store-and-forward transport protocol for ANA.** This is a software deliverable.

Task 2.2: Functional Composition **Task Leader: ULANC**
[8PM: ULANC 8]

- Continuation from M24
- Task description:
  The main aim of this task is the design and development of the framework that will constitute the basic network subsystem in the ANA node (essentially a replacement for the traditional network stack) by means of which it will be possible dynamically and flexibly integrate new and evolving network functionalities and carry out its autonomic reconfiguration procedures. During the subsequent 18 months of the project this task will focus on the following areas:
  Finalization of the development of the information collection and sharing framework, which will drive dynamic cross-layer/component optimizations and adaptation of the ANA network subsystem in collaboration with work on Task3.1.
  Using information sensing (environmental awareness) to drive functional composition (providing hints/heuristics that characterize the operational environment)
- Deliverable:
  M36, D.2.12 – **Integration of the Functional Composition Framework and Evaluation.** This deliverable includes software.

Task 2.3: Service Placement, Advertisement and Discovery **Task Leader: NKUA**
[14PM: NKUA 14]

- Continuation from M24
- Task description:
  In this task the development of efficient algorithms that will enable service discovery in ANA will continue. A holistic approach will be followed, considering the various elements and processes that are involved, such as service placement and migration, service advertisement and service searching for. The main aim is to provide for a scalable solution in "unstructured" network environments where the size of the network can be arbitrarily large and the network dynamics significant (nodes entering, departing, variation regarding the content availability, etc.). The continuation of this work is mostly of analytical nature, accompanied with simulation results whenever this is necessary. In addition to the algorithmic aspects of the aforementioned mechanisms, a design process will follow aiming at incorporating the

particular algorithms in the ANA communication system, exploring also the possibility of further implementation.
More specifically the following topics will be the basis of the conducted research:
  - Algorithms for efficient service provision placement and migration when multiple service facilities are available in the network.
  - Service advertisement (push mode) and service search for (pull mode) will continue to be investigated with emphasis on a scalable and low overhead approach.
  - Design and development of the service discovery mechanisms.
- Deliverable:
  M36, D.2.13 – **Service Discovery Phases: Conceptual Design and Evaluation.**

Task 2.4: Self-Association and Self-Organisation **Task Leader: NEC**
[22PM: UBASEL 6, NEC 7, UWATER 9]

- Continuation from M24
- Task description:
  The primary goal of this task is the development of functions that will enable the ANA node to auto-configure and associate itself with a network compartment and mechanisms that allow the nodes of a compartment to self-organize in the given context/environment.
  This task will therefore design the necessary ANA node functions to allow a network node (or communication entity) to bootstrap itself into compartments. This includes the zero-configuration of the node when it "boots up", discovers its context and joins an available compartment as well as addressing and intra-compartment routing. The proposed self-association scheme will be implemented and finally integrated into the basic prototype system of ANA (developed as part of WP1).
  Another focus of this task is to explore particular self-organization approaches for compartments. As a result, the objective of this task is to design and develop a few self-organization algorithms for intra-compartment organization and handling of communication entities, including aspects of addressing and routing in an autonomic manner.
  Finally, it is also envisaged to validate such a compartment for a spontaneous networking scenario by integrating an experimental compartment implementation into the ANA prototype and testbed.
  More specifically the following topics will be the basis of the conducted research:
  - Finalization of the ongoing design and development work of the self-association and self-organization/routing concepts
  - Prototypical implementation and integration of developed functionalities
- Deliverable:
  M36, D.2.14 – **Implementation of Self-Association and Self-Organisation Mechanisms.**
  This deliverable includes software.

Task 2.5: Customization of Overlay Compartments **Task Leader: UIO**
[6PM: UIO 6]

- Continuation from M24
- Task description:
  The goal of this task is to study and deliver the algorithms, abstractions and interfaces that

will allow customization of overlay compartments to match the service and application requirements.
Based on an exemplary service, namely an on-demand media streaming service, which is provisioned by an overlay compartment, this task will examine to what extend the ANA abstractions (e.g. Information Channels, Information Dispatch Points and Information Flows) will benefit customization of the service.
The main goal for the upcoming 18 month (M25-M42) is therefore to complete the development of the proof-of-concept streaming service and to evaluate the advantage of ANA with a traditional Internet-based approach. This includes a study how application development in general can benefit from the available ANA interfaces and functionalities rather than implementing it in the application directly.

– Deliverable:
  M36, D.2.15 – **Implementation and Integration of the proof-of-concept overlay streaming compartment.** This deliverable includes software.

Task 2.6: Integrated Service Provisioning, Service Discovery & Routing Task Leader: UPMC
[27PM: UPMC 14, NKUA 4, UWATER 9]

– Continuation from M24
– Task description:
  Services and content are potentially provided by a large variety of entities in an ANA world. They will be made available, advertised and accessed efficiently as naturally supported by the ANA routing framework. The system can be perceived as a virtual distributed database, accessed by clients through service requests.
  Two complementary levels are considered: *intra* and *inter*-compartment.
  For *intra*-compartment, a content-based routing approach, in which routing decisions are driven by the content (i.e. services) requested by the communicating entities will be developed. Services will be published and pushed towards those entities who have subscribed to it. Requests can be based on simple attributes as well as regular expressions.
  This infrastructure will span multiple heterogeneous compartments. Because compartments may have different service advertisement and discovery mechanisms, different service descriptions and different administrative policies, this task will also explore an *inter*-compartment service discovery architecture that allows service advertisement, discovery, and selection across compartments.
  The challenge of content-based intra- and inter-compartment routing will be to formulate efficient and reliable means to determine routes, and to maintain the routing information over a highly dynamic, large-scale service infrastructure. Routing decisions will be determined by matching the attributes of the service to be discovered against predicates at content-aware nodes. Key issues that will be addressed in the development of the content-based inter-compartment communication infrastructures are efficiency, flexibility, robustness, and scalability.
  More specifically the following topics will be the basis of the conducted research:
  – Development and evaluation of content-based routing mechanisms.
  – Integration of the three service discovery phases (service placement, service advertisement and service discovery) with content-based routing concepts, and evaluation in realistic scenarios using analytical and simulation tools.

  - Design and evaluation of inter-compartment service discovery mechanisms for ANA.
- Deliverable:
  M36, D.2.16 – **Final design, evaluation and prototype implementation of content-based routing mechanism.** This deliverable includes software.

8.7.3 Milestones and expected results

M.2.4 Implementation of the different communication systems functions completed
Marks the beginning of the integration and evaluation phase of the ANA communication system. (M36)

8.7.4 Deliverables

D.2.9 **Design and implementation of an intra-compartment routing scheme** (Software) (M30, ETHZ)

D.2.10 **Implementation of inter-compartment communication schemes** (Software) (M36, ETHZ)

D.2.11 **Implementation of a store-and-forward transport protocol for ANA** (Software) (M42, ETHZ)

D.2.12 **Integration of the Functional Composition Framework and Evaluation** (Including Software) (M36, ULANC)

D.2.13 **Service Discovery Phases: Conceptual Design and Evaluation** (M36, NKUA)

D.2.14 **Implementation of Self-Association and Self-Organization Mechanisms** (Including Software) (M36, NEC)

D.2.15 **Implementation and Integration of the proof-of-concept overlay streaming compartment** (Including Software) (M36, UIO)

D.2.16 **Final design, evaluation and prototype implementation of content-based routing mechanism** (Including Software) (M36, UPMC)

8.8 Workpackage 3: Self-management

Workpackage number	1				Start date or starting event	M6
Workpackage title	Self-management, Resilience and Security				Leader	ULG
Participant id	1 ETHZ	2 UBASEL	3 NEC	4 ULANC	5 FOKUS	6 ULG
Person-months per participant:	12	0	0	18	13	20
Participant id	7 UPMC	8 NKUA	9 UIO	10 TA	11 UWATER	
Person-months per participant:	0	0	24	0	9	

8.8.1 Objectives

The goal of the Work Package is to establish principles, mechanisms and proof-of-concepts necessary for autonomic network self-management, at the node and compartment levels. This encompasses monitoring, optimization and resilience.

At the end of the second project year (M24), a set of independent monitoring bricks have been implemented along the lines of the monitoring framework proposed during the first year.

The goal of the next 18 months is twofold:

- To design and validate advanced self-* features (= Conceptual thread);
- To develop and validate an integrated management system, including Monitoring, Failure Detection and Fault Management (= Implementation thread).

In the conceptual thread, we will pursue a series of complementary research topics that all have the common goal of designing advanced self-* features. Among them we find a self-adaptive MCIS (Multi-Compartment Information Sharing), a self-organized coordinate system, adaptive traffic management, mobility monitoring and prediction, self-optimization and stabilization, cross-layer optimization, and measurement-based resilience mechanisms. These tasks are detailed below.

In the implementation thread, the existing independent bricks will be integrated together. Then the functionality of this prototype will evolve to include the more advanced self-* features defined above.

At M30, a first integrated implementation of a complete monitoring system will be available, including a basic MCIS and a basic Coordinate System. This implementation will be integrated with other modules and tested until M36. Some failure detection and fault management mechanisms will also be implemented, such as the Incident Dissemination Engine (IDE) and parts (i.e., registries) of the Challenge Detection Engine (CDE).

At M36, this implementation will be further extended with a self-adaptive MCIS and adaptive traffic management features.

At M42 the goal is to add some mobility monitoring and prediction facilities, a self-organized coordinate system, and measurement-based resilient mechanisms.

8.8.2 Description of work

WP3 is divided into three related tasks described in more detail below. Expected results are both conceptual and practical as they will be validated by simulations and experimented over the Testbed.

They will cover all the necessary aspects of management, such as monitoring, optimization, and resilience.

Task 3.1: Monitoring **Task Leader: UIO**
[40PM: ETHZ 12, FOKUS 8, ULG 5, UIO 15]

- Continuation from M24
- Task description:
  In this task we will design, implement and validate monitoring mechanisms and use cases. This task is composed of 4 subtasks.
  - Implementation, integration and validation of a monitoring system (UIO, FOKUS, ULG, ETHZ):
    We have a set of independent monitoring bricks along the lines of our monitoring framework. These bricks will be integrated together and the functionality of this prototype will also evolve to include more advanced self-* features such as a self-

adaptive MCIS, a virtual coordinate system (VC), adaptive traffic management, and mobility monitoring and prediction.

- *Adaptive Traffic Measurement (FOKUS):*
  In the first phase 3 initial bricks for realizing an adaptive monitoring scenario have been designed and implemented: Packet capturing, Adaptive Sampling and System Monitoring. In order to support an anomaly detection scenario with the adaptive monitoring compartment we will design and implement bricks for adaptive flow classification, aggregation and data analysis. Those bricks will be integrated into the adaptive monitoring compartment.
- *Wireless quality monitoring and mobility prediction (ETHZ):*
  We propose to develop a pattern matching-based scheme to predict (i) link quality variations and (ii) link residual lifetime. The idea is that this mechanism does not require the use of any external hardware, it relies simply on monitoring Signal to Noise Ratio (SNR) as a quality measure. Nodes monitor and store the SNR of links to their neighbours in order to obtain a time series of SNR measurements. When a prediction on the future state of a link is required, a node looks for similar patterns to the current situation in the past (time series) using a cross-correlation function. The matches found are then used as a base for the prediction. Clearly, our method will take advantage of the occurrence and recurrence of patterns in human motion, which are reflected in SNR measures. It focuses only on the scale of links and as such is complementary to mobility prediction schemes working at the macroscopic level (i.e., AP occurrences) which target mobility prediction at a broader scale.
- *Use cases of monitoring services (UIO):*
  We want to investigate the integration of the monitoring framework to the services that wish to use them in some different use cases. Our goal is to come up with new types of monitoring services that scale better in functionality and efficiency than the tools of today. One concrete example is a Traffic monitoring and query framework: we will examine traffic load/type parameters (e.g., available bandwidth, packet loss) that can be maintained or calculated by nodes, and the associated overhead and resource requirements; and we will examine consequences of resource requirements for different node types, especially more constrained ones such as handheld devices and personal computers.

- Deliverable:
  M36, D.3.7 – **Integrated monitoring support in ANA** (document + software deliverable)

Task 3.2: Self Optimization **Task Leader: ULG**

[33PM: ULG 15, UIO 9, UWATER 9]

- Continuation from M24
- Task description:
  In this task we will design and validate mechanisms for self-adaptation, self-optimization and stabilization. This task is composed of 4 subtasks.
  - *Self-adaptation of the MCIS system (UIO)*:
    We will find out solutions for *adaptive indexing* of the range data as opposed to the systematic static indexing approach employed currently by the system. Our objective is to find indexing strategies that adapt the indexing process based on the

usage (e.g. query and storage rates and data properties) and the environment (e.g. number of nodes).
Currently, the MCIS system applies explicit load balancing strategy for each data compartment separately in order to cope with unevenly distributed values of data. Our objective is to extend the load balancing strategy on another level, namely across these data compartments, i.e. to come up with *multi-compartment load balancing* strategies.
Currently the MCIS supports only single attribute indexes via the attribute hubs. We aim to evaluate how we can extend the system to support multi-attribute indexes.

- *Self-organized clustering of the coordinate system* (ULG):
During the second year, we have shown how a coordinate system can be used in the monitoring framework to optimize the RTT measurements, but it is known that such coordinate systems are not accurate when TIVs (Triangular Inequality Violations) are present in the network. We proved that a hierarchical coordinate system, running both a local and a global coordinate systems, with the goal of having very few TIVs at the local level, would be more accurate. The next step consists in designing an algorithm that will allow nodes to cluster themselves autonomically to form a two-tier and accurate coordinate system.
- *Self-optimization and stabilization* (UWATER):
In examining the self-optimization problem of large autonomous and distributed system, we attempt to provide theoretical analysis on the properties of stabilization and distributed optimization. In stabilization, we investigate under what conditions, would distributed (and often selfish) component behaviours leads to global stable system states. In distributed optimization, we study how distributed decision making based on local knowledge lead to global optima for the entities and for the system.
- *Cross-layer optimization* (UWATER):
P2P traffic constitutes a significant percentage of all network traffic. This work focuses on how ISPs can cooperate with a P2P network in order to place content while avoiding the costs corresponding to heavy inter-compartmental traffic. To this end, we have adopted a cost scenario based on the so-called Min-Max Multiway Cut problem which allows us to formulate an initial model of data placement and consequent inter-compartmental traffic. A heuristic based on semidefinite programming has been developed which allows us to obtain solutions to the problem under this model. Current research is underway to further develop this model and execute large scale experiments to test the effectiveness of our heuristic.

- Deliverable:
M36, D.3.8 - **Self-optimization Mechanisms**

Task 3.4: Resilience **Task Leader: ULANC**
[23PM: ULANC 18, FOKUS 5]

- Continuation from M24
- Task description:
In this task we will design, implement and validate failure detection, fault management and resilience mechanisms. This task is composed of two subtasks with their own deliverables.

- *Failure Detection and Fault Management Mechanisms (FOKUS)*
  We developed a Unified Framework and an ANA-specific framework, for Implementing Autonomic Fault-Management and Failure-Detection for Self-Managing Networks. Our plan is to refine parts of the architecture and implement selected components and interfaces of the architecture as ANA bricks with corresponding APIs. Of particular interest will be the Incident Information Dissemination Engine (IDE), the Registry or Registries of the Challenge Detection Engine (CDE) for registering information about node-local incidents (faults, errors, failures, alarms), as well as incidents received by the IDE from the network. If time and our limited resources allow, we will also look into some minimal functionality of the core functions of the two engines.
- *Measurement-based Resilience Mechanisms (ULANC)*
  We have identified a number of measurement-based research activities to investigate the extent to which physical infrastructure and protocol behaviour influence the end-to-end network performance. Based on measurement analysis, we plan to design mechanisms that will enhance the network resilience properties under specific operational scenarios, at a distributed system and/or protocol level. More specifically, we aim to look at detection mechanisms for abnormal network behaviour, the feasibility of incorporating resilient modes of operation within protocol structures, and the cost (system overhead) of measurement and control sub-systems. We intend to contribute prototype implementations deriving from this work in the context of self-* mechanisms so as to demonstrate their applicability in the context of the ANA architecture, and depending on the availability of the required coupling components from other tasks (info flow, routing and transport, etc).

- Deliverable:
  M36, D.3.9 – **Implementation of selected components of the failure detection and fault management part of the ANA architecture** (Software deliverable + documentation).
  M36, D.3.10 – **Measurement-based Resilience Mechanisms**

8.8.3 Milestones and expected results

M.3.3 First integrated implementation of a complete monitoring system, including MCIS and Coordinate System, IDE and parts (registries) of the CDE. (M30, UIO)

M.3.4 Four deliverables plus extended implementation, including a self-adaptive MCIS and adaptive traffic management. (M36, ULG)

M.3.5 Extended implementation, including the mobility monitoring, the self-organized coordinate system and measurement-based resilient mechanisms. (M42, ETHZ)

8.8.4 Deliverables

D.3.7 **The monitoring part of the ANA architecture – version 2** (M36, UIO)

D.3.8 **Self-optimization mechanisms** (M36, ULG)

D.3.9 **Implementation of selected components of the failure detection and fault management** (M36, ULANC)

D.3.10 **Measurement-based Resilience Mechanisms** (M36, ULANC)

8.9 Workpackage 4: Integration, Applications and Testbed

Workpackage number	4			Start date or starting event		M6
Workpackage title	Integration, applications, and Testbed				Leader	ULANC
Participant id	1 ETHZ	2 UBASEL	3 NEC	4 ULANC	5 FOKUS	6 ULG
Person-months per participant:	8	11	10	5	12	5
Participant id	7 UPMC	8 NKUA	9 UIO	10 TA	11 UWATER	
Person-months per participant:	4	3	6	6	0	

8.9.1 Objectives

The goal of the ANA project is to explore novel ways of organising and using networks beyond legacy Internet technology. The ultimate goal is to design and develop a novel network architecture that can demonstrate the feasibility and properties of autonomic networking. As specified in the description of work, it is the intension of the project to address the self-* features of autonomic networks such as auto-configuration, self-organisation, self-optimisation, self-monitoring, self-management, self-repair, and self-protection.

The activities in work package 4 in general comprise the "output interface" of the ANA project towards the outside world.

8.9.2 Description of work

WP4 is divided into four tasks. Expected results are largely practical in nature and are described in more detail below.

Task 4.1: Testbed and Tools **Task Leader: ULANC**

[10PM: UBASEL 6, ULANC 1, ULG 3]

- Continuation from M24
- Task description:
  This task aims to support the development and testing process within the project by providing a distributed set of ANA nodes over which partners can carry out experiments and system texting. This task is composed of 3 subtasks.
  - *ANALab and ANA@Home System (UBASEL):*
    UBASEL will carry on the development of the ANALab software for monitoring and possibly configuring ANA nodes via a web-based interface. Part of this work will be done in collaboration with ULANC in order to produce the mechanisms for getting monitoring data and configuring ANA nodes remotely. The web-based interface will be developed by UBASEL while ULANC concentrates on the Nagios (http://www.nagios.org/) extension.
    UBASEL will also tightly integrate the ANALab and standard ANA Node software in order to produce a first prototype version of the ANA@Home software. The objective of ANA@Home is to enable remote researchers to join the ANA Testbed and participate in experiments and testing. In the first instance, this external access will be controlled and restricted.

- *ANALab Management System (ULANC):*
  ULANC will continue work on the Nagios based monitoring facility for the ANA Testbed and cooperate with UBASEL on enriching the ANALab testbed management suite. This effort will allow experiments to be remotely scheduled on the Testbed and any resulting logging information to be collected.
- *On-demand loading & configuring framework (ULG):*
  ULG will prototype an environment capable of hosting several bricks in a single user-level process. This environment should be capable of interpreting dependencies within a collection of bricks and automatically load and configure them, for example, as result of a compartment lookup in node compartment. (This work will pick up on work within task 2.4). We will also work on easing the support of information hook in ANA bricks.

- Deliverable:
  M36, D.4.5 – **Extended Integrated Test-bed Infrastructure**

Task 4.2: ANA Demonstration and Visualisation **Task Leader: UIO**
[15PM: ETHZ 4, UBASEL 2, NEC 2, NKUA 1, UIO 6]

- Continuation from M24
- Task description:
  The primary goal of task 4.2 "Demonstrations & Visualizations" is to create a demonstration that can be used to showcase the achievements of the various ANA tasks.
  - *Demonstration and Visualisation (UIO):*
    The demonstration will be based on a physical demo unit, running an overlay/ P2P Video-on-Demand (VoD) streaming application developed in task 2.5. The application will integrate implemented ANA bricks in an overlay compartment. The aim is to allow users to judge the perceptual QoS of the video stream by showing a streamed movie on a typical consumer set-top box. Two demonstration modes will be available. Firstly, an ANA testbed mode that demonstrates the ability of the system to work with the actual Internet and deal with the unpredictable nature of WAN traffic. Secondly, a simulation mode that gives a more controlled environment, where it is possible to demonstrate scenarios that cannot be realized on the ANA testbed, due to limited size, possible traffic types, and geographical node distribution.
    The system will offer node management functions and show a map of the network topology, with a visual display of the traffic patterns generated by both the data traffic and the monitoring framework.
    The task starts in month 36, and a delivery will be made in month 39, describing the planned design and detailed composition of the demo, based on the ANA functionality implemented at that point.
    The aim will be to deliver a code required to build the demo in month 48. The task will also provide a demo unit running on a set-top box/ laptop combination.
  - *IP to ANA Adaptation Layer (UBASEL):*
    UBASEL will implement a first prototype of the IP to ANA adaptation layer. This will permit to use IP based applications over ANA by emulating the operation of "IP

protocols" like DNS and ARP. The outcome is a software deliverable at M30 (will also include a report describing the final design).

- Deliverable:
  M30, D.4.6 – **IP to ANA Adaptation Layer**
  M39, D.4.7 – **Description of VoD demonstrator design and composition**

Task 4.3: Integration **Task Leader: ETHZ**

[31PM: ETHZ 4, UBASEL 3, NEC 8, ULANC 4, FOKUS 4, ULG 2, UPMC 4, NKUA 2]

- Starting date: M24
- Task description:
  The aim of this task is to pull together the work carried out in the other work packages and to evaluate the progress toward a usable ANA platform.
  - *Overall Integration (UBASEL, ULG, NEC)*
    This task will re-evaluate the feasibility of building an autonomic ANA node based on the set of "bricks" currently being developed, with the aim of identifying:
    - Missing components
    - Missing interfaces, information elements, etc.
  - The task will define how the various components can/ should work together to achieve autonomic behaviour in ANA nodes/ networks. Results should help steering the remaining developments in WP2 and WP3 and the integration.
    UBASEL will also contribute to the release of a coherent ANA Node by helping all brick developers to properly integrate their bricks into the existing software framework (i.e. use of appropriate development templates and functions) and ANA environment (i.e. correct use of the compartment API).
    A document, "Integration Guidelines" summarising lessons from this task the final ANA Distribution will be available in month 30.
  - *Yellow-pages System (UBASEL)*
    This task focuses on the integration of the compartment "yellow-pages" system with all the existing compartments that will be developed in 2008. UBASEL will help developers to populate and use the yellow-pages system in order to ease inter-compartment communications.
  - *Service Discovery (NKUA)*
    This task will develop a tool for the visualization of ANA specific service discovery algorithms with consideration for the ANA node environment to enable future integration.
  - *Monitoring (FOKUS)*
    FOKUS is developing bricks that can be applied for various traffic monitoring tasks. The bricks provide functionality for packet capturing, flow classification, sampling, monitoring of system parameters and data aggregation. Integration work on these bricks will demonstrate the realisation of adaptive monitoring depending on situational parameters, for example, within an anomaly detection scenario.

  - *Virtual Coordinate Monitoring (ULG)*
    The Virtual Coordinate brick implemented by ULG will be integrated with the other bricks of the monitoring framework (active probing, MCIS, orchestration). It will be used to provide accurate virtual coordinates to nodes, and thereby optimize the RTT measurements between any pair of nodes.
  - *Functional Composition (ULANC)*
    This task builds on the work in task 2.2 on the functional composition framework; ULANC plans to spend some effort integrating this in the wider ANA software suite.
  - *Core Implementation (ETHZ)*
    In addition to their coordinating role for the integration effort, ETHZ will continue to extend the core ANA implementation and assist partners in developing bricks for the ANA system.
- Deliverable:
  M36, D.4.8 – **Integration Guidelines for the final ANA Distribution**

Task 4.4: Testing **Task Leader: FOKUS**
[14PM: FOKUS 8, TA 6]

- Starting date: M30
- Task description:
  This task addresses the testing needs of developers within tasks 4.2 and 4.3. Work will target testing of both the ANA application and the bricks developed to deliver the ANA platform.
  - Application Testing (TA):
    We are interested to guarantee that current internet applications can expect to find usable the legacy communication interfaces. In that respect throughout these interoperability tests we would like to confirm the correctness of operation of the traditional socket APIs, and transport protocol operation.
    It is the intention that TA will conduct application testing in the later parts of the project which will suitably exercise and assess the ANA platform.
  - Test Cases (FOKUS):
    This task will develop an ANA test environment which is based on the TTCN-3 (Testing and Test Control Notation) technology. It will offer selected test cases to test the conformance and interoperability of ANA bricks and applications. The test environment will contain:
    - Predefined TTCN-3 modules, which can be customized and extended for specific bricks and applications,
    - Adapters, which enable the automated execution of the tests, and
    - Guidelines for how to develop tests within the ANA testbed.
- Deliverable:
  M36, D.4.9 – **Test Environment and Guidelines for ANA Application and Brick Tests**

8.9.3 Deliverables

D.4.5 **Extended Integrated Test-bed Infrastructure** (M36, ULANC)

D.4.6 **IP to ANA Adaptation Layer** (M30, UBASEL)

D.4.7 **Description of VoD demonstrator design and composition** (M39, UIO)

D.4.8 **Integration Guidelines for the final ANA Distribution** (M36, ETHZ)

D.4.9 **Test Environment and Guidelines for ANA Application and Functional Block Tests** (M36, FOKUS)

8.10 Budget Overview

8.10.1 IP Efforts for the third 18 months period (IP Efforts Form 2)

IP Activity Type	ETHZ	UBASEL	NEC	ULANC	FOKUS	ULG	UPMC	NKUA	UIO	TA	UWATER	Total Activities
RTD/Innovation activities												
WP0 Project Management and Dissemination	3	2	3	2	0	2	0	2	0	0	2	16
WP 1 Archtitecture	8	10	4	0	0	4	0	0	0	0	0	26
WP2 Autonomic Communication System	12	15	10	8	0	0	14	18	6	0	18	101
WP3 Self-Management, Resilience, and Security	12	0	0	18	13	20	0	0	24	0	9	96
WP4 Integration, Applications, and Testbed	8	11	10	5	12	5	4	3	6	6	0	70
Total "research"	43	38	27	33	25	31	18	23	36	6	29	309
Demonstration Activities												
WP 1 Archtitecture	0	0	0	0	0	0	0	0	0	0	0	0
WP2 Autonomic Communication System	0	0	0	0	0	0	0	0	0	0	0	0
WP3 Self-Management, Resilience, and Security	0	0	0	0	0	0	0	0	0	0	0	0
WP4 Integration, Applications, and Testbed	0	0	0	0	0	0	0	0	0	0	0	0
Total "Demonstration"	0	0	0	0	0	0	0	0	0	0	0	0
Training Activities												
WP 1 Archtitecture	0	0	0	0	0	0	0	0	0	0	0	0
WP2 Autonomic Communication System	0	0	0	0	0	0	0	0	0	0	0	0
WP3 Self-Management, Resilience, and Security	0	0	0	0	0	0	0	0	0	0	0	0
WP4 Integration, Applications, and Testbed	0	0	0	0	0	0	0	0	0	0	0	0
Total "Training"	0	0	0	0	0	0	0	0	0	0	0	0
Consortium Management Activities												
WP0 Project Management and Dissemination	6	0	0	0	0	0	0	0	0	0	0	6
WP 1 Archtitecture	0	0	0	0	0	0	0	0	0	0	0	0
WP2 Autonomic Communication System	0	0	0	0	0	0	0	0	0	0	0	0
WP3 Self-Management, Resilience, and Security	0	0	0	0	0	0	0	0	0	0	0	0
WP4 Integration, Applications, and Testbed	0	0	0	0	0	0	0	0	0	0	0	0
Total "Management"	6	0	0	0	0	0	0	0	0	0	0	6
Total Participants	49	38	27	33	25	31	18	23	36	6	29	315

8.10.2 Budget for the third 18 months (Form A3.3 from CPFs)

Proposal Number	027489			Proposal Acronym	ANA			

Financial Information - third 18 month of the project										
Participant	Short Name	CostModel	Estimated eligible costs and requested EC contribution		Costs and EC contribution per type of activities				Total	Total receipts
					RTD	Demonstration	Training	Consortium Management		
	ETHZ	AC	Eligible Costs	Direct Costs	270'711.00	1'875.00		36'392.00	308'978.00	
				of which subcontracting						
				Indirect Costs	37'900.00	1'875.00		4'780.00	44'555.00	
				Total eligible Costs	308'610.00	0.00		41'172.00	349'782.00	
			Requested EC Contribution		308'610.00	1'875.00		41'172.00	351'657.00	
2	U Basel	AC	Eligible Costs	Direct Costs	228'328.00	1'875.00		2'250.00	232'453.00	
				of which subcontracting						
				Indirect Costs	45'666.00	1'875.00		0.00	47'541.00	
				Total eligible Costs	273'993.00	0.00		2'250.00	276'243.00	
			Requested EC Contribution		273'993.00	1'875.00		2'250.00	278'118.00	
3	NEC	FC	Eligible Costs	Direct Costs	198'944.00	1'875.00		2'250.00	203'069.00	
				of which subcontracting						
				Indirect Costs	117'680.00	1'875.00		0.00	119'555.00	
				Total eligible Costs	316'624.00	0.00		2'250.00	318'874.00	
			Requested EC Contribution		158'312.00	1'875.00		2'250.00	162'437.00	
4	U Lanc	AC	Eligible Costs	Direct Costs	187'304.00	1'875.00		2'250.00	191'429.00	
				of which subcontracting						
				Indirect Costs	37'461.00	1'875.00		0.00	39'336.00	
				Total eligible Costs	224'765.00	0.00		2'250.00	227'015.00	
			Requested EC Contribution		224'765.00	1'875.00		2'250.00	228'890.00	
5	FOKUS	FC	Eligible Costs	Direct Costs	142'109.00	1'875.00		2'250.00	146'234.00	
				of which subcontracting						
				Indirect Costs	130'609.00	1'875.00		0.00	132'484.00	
				Total eligible Costs	272'718.00	0.00		2'250.00	274'968.00	
			Requested EC Contribution		136'359.00	1'875.00		2'250.00	140'484.00	
6	U Liege	AC	Eligible Costs	Direct Costs	149'436.00	1'875.00		2'250.00	153'561.00	
				of which subcontracting						
				Indirect Costs	29'887.00	1'875.00		0.00	31'762.00	
				Total eligible Costs	179'324.00	0.00		2'250.00	181'574.00	
			Requested EC Contribution		179'323.00	1'875.00		2'250.00	183'448.00	
7	UPMC	AC	Eligible Costs	Direct Costs	109'350.00	1'875.00		2'250.00	113'475.00	
				of which subcontracting						
				Indirect Costs	21'870.00	1'875.00		0.00	23'745.00	
				Total eligible Costs	131'220.00	0.00		2'250.00	133'470.00	
			Requested EC Contribution		131'220.00	1'875.00		2'250.00	135'345.00	
8	NKUA	AC	Eligible Costs	Direct Costs	148'566.67	1'875.00		2'250.00	152'691.67	
				of which subcontracting						
				Indirect Costs	29'713.33	1'875.00		0.00	31'588.33	
				Total eligible Costs	178'280.00	0.00		2'250.00	180'530.00	
			Requested EC Contribution		178'280.00	1'875.00		2'250.00	182'405.00	
9	UiO	AC	Eligible Costs	Direct Costs	182'379.00	1'875.00		2'250.00	186'504.00	
				of which subcontracting						
				Indirect Costs	36'476.00	1'875.00		0.00	38'351.00	
				Total eligible Costs	218'855.00	0.00		2'250.00	221'105.00	
			Requested EC Contribution		218'854.00	1'875.00		2'250.00	222'979.00	
10	TA	FC	Eligible Costs	Direct Costs	70'743.75	1'875.00		2'250.00	74'868.75	
				of which subcontracting						
				Indirect Costs	16'406.25	1'875.00		0.00	18'281.25	
				Total eligible Costs	87'150.00	0.00		2'250.00	89'400.00	
			Requested EC Contribution		43'575.00	1'875.00		2'250.00	47'700.00	
11	UW	AC	Eligible Costs	Direct Costs	0.00	0.00		0.00	0.00	
				of which subcontracting						
				Indirect Costs	0.00	0.00		0.00	0.00	
				Total eligible Costs	0.00	0.00		0.00	0.00	
			Requested EC Contribution		0.00	0.00		0.00	0.00	
Total			Eligible Costs		2'191'539.00	0.00		61'422.00	2'252'961.00	
			Requested EC contribution		1'853'291.00	18'750.00		61'422.00	1'933'463.00	

Any Supplementary reports which have been specified in any annex of the contract to be prepared at each periodic reporting period will also now be submitted.

9 Project Resources and Budget Overview

9.1 IP Efforts for the full duration of the project (IP Efforts Form 1 - see Appendix 1)

IP Activity Type	RTD / Innovation activities	Demonstration activities	Training activities	Consortium management activities	Total per PARTICIPANT
ETHZ	64	1	0	15	80
Ubasel	67	1	0	2	70
NEC	62	1	0	0	63
Ulanc	71	1	0	0	72
Fokus	62	1	0	0	63
ULg	76	1	0	0	77
UPMC	66	1	0	0	67
NKUA	53	1	0	0	54
UiO	74	1	0	0	75
TA	21	1	0	0	22
U Water	71	1	0	0	72
Total per ACTIVITY	687	11	0	17	
Overall Total efforts					715

9.2 Overall budget for full duration of the project (Forms A3.1 & A3.2 from CPFs)

9.2.1 Form A3.1

Proposal Number	027489			Proposal Acronym	ANA			

Financial Information - whole duration of the project										
Participant	Short Name	CostModel	Estimated eligible costs and requested EC contribution		Costs and EC contribution per type of activities				Total	Total receipts
					RTD	Demonstration	Training	Consortium Management		
	ETHZ	AC	Eligible Costs	Direct Costs	633,487.00	10,690.00		94,356.00	738,533.00	
				of which subcontracting						
				Indirect Costs	109,478.00	1,138.00		17,071.00	127,687.00	
				Total eligible Costs	742,966.00	11,828.00		111,427.00	866,221.00	
			Requested EC Contribution		742,965.00	11,828.00		111,427.00	866,220.00	
2	U Basel	AC	Eligible Costs	Direct Costs	413,556.00	10,689.00		20,378.00	444,623.00	
				of which subcontracting						
				Indirect Costs	82,711.00	1,138.00		2,276.00	86,125.00	
				Total eligible Costs	496,267.00	11,827.00		22,654.00	530,748.00	
			Requested EC Contribution		496,267.00	11,827.00		22,653.00	530,747.00	
3	NEC	FC	Eligible Costs	Direct Costs	461,334.00	11,918.00		9,000.00	482,252.00	
				of which subcontracting						
				Indirect Costs	270,228.00	4,359.00		0.00	274,587.00	
				Total eligible Costs	731,562.00	16,277.00		9,000.00	756,839.00	
			Requested EC Contribution		365,781.00	5,697.00		9,000.00	380,478.00	
4	U Lanc	AC	Eligible Costs	Direct Costs	430,477.00	10,308.00		9,000.00	449,785.00	
				of which subcontracting						
				Indirect Costs	86,095.00	1,062.00		0.00	87,157.00	
				Total eligible Costs	516,572.00	11,370.00		9,000.00	536,942.00	
			Requested EC Contribution		516,572.00	11,369.00		9,000.00	536,941.00	
5	FOKUS	FC	Eligible Costs	Direct Costs	406,682.00	10,198.00		9,000.00	425,880.00	
				of which subcontracting						
				Indirect Costs	376,154.00	5,224.00		0.00	381,378.00	
				Total eligible Costs	782,836.00	15,422.00		9,000.00	807,258.00	
			Requested EC Contribution		391,418.00	5,398.00		9,000.00	405,816.00	
6	U Liege	AC	Eligible Costs	Direct Costs	368,971.00	9,429.00		9,000.00	387,400.00	
				of which subcontracting						
				Indirect Costs	73,794.00	886.00		0.00	74,680.00	
				Total eligible Costs	442,765.00	10,315.00		9,000.00	462,080.00	
			Requested EC Contribution		442,766.00	10,314.00		9,000.00	462,080.00	
7	UPMC	AC	Eligible Costs	Direct Costs	259,200.00	10,400.00		9,000.00	278,600.00	
				of which subcontracting						
				Indirect Costs	51,840.00	1,080.00		0.00	52,920.00	
				Total eligible Costs	311,040.00	11,480.00		9,000.00	331,520.00	
			Requested EC Contribution		311,040.00	11,480.00		9,000.00	331,520.00	
8	NKUA	AC	Eligible Costs	Direct Costs	359,233.00	10,833.00		9,000.00	379,066.00	
				of which subcontracting						
				Indirect Costs	71,847.00	1,167.00		0.00	73,014.00	
				Total eligible Costs	431,080.00	12,000.00		9,000.00	452,080.00	
			Requested EC Contribution		431,080.00	12,000.00		9,000.00	452,080.00	
9	UiO	AC	Eligible Costs	Direct Costs	439,057.00	9,729.00		9,000.00	457,786.00	
				of which subcontracting						
				Indirect Costs	87,811.00	946.00		0.00	88,757.00	
				Total eligible Costs	526,869.00	10,675.00		9,000.00	546,544.00	
			Requested EC Contribution		526,869.00	10,674.00		9,000.00	546,543.00	
10	TA	FC	Eligible Costs	Direct Costs	198,416.00	14,766.00		9,000.00	222,182.00	
				of which subcontracting						
				Indirect Costs	46,484.00	2,734.00		0.00	49,218.00	
				Total eligible Costs	244,900.00	17,500.00		9,000.00	271,400.00	
			Requested EC Contribution		122,450.00	6,125.00		9,000.00	137,575.00	
11	UW	AC	Eligible Costs	Direct Costs	0.00	0.00		0.00	0.00	
				of which subcontracting						
				Indirect Costs	0.00	0.00		0.00	0.00	
				Total eligible Costs	0.00	0.00		0.00	0.00	
			Requested EC Contribution		0.00	0.00		0.00	0.00	
Total			Eligible Costs		5,226,857.00	128,694.00		206,081.00	5,561,632.00	
			Requested EC contribution		4,347,208.00	96,712.00		206,080.00	4,650,000.00	

9.2.2 Form A3.2

Proposal Number	027489	Proposal Acronym	ANA

Estimated Breakdown of the EC contribution per reporting period			
Reporting Periods	Month	Estimated Grant to the Budget	
		Total	first 6 month
Reporting Period 1	M1 - M12	800000	
Reporting Period 2	M13- M24	1350000	895000
Reporting Period 3	M25- M 36	1300000	550000
Reporting Period 4	M37 - M48	1100000	500000
Reporting Period 4	M49 - M60	0	0

9.3 IP management level description of resources and budget

The objectives of the ANA integrated project are ambitious in many ways. The scientific objective, i.e. *to identify fundamental autonomic networking principles*, involves a significant and coordinated amount of fundamental research that requires strong and complementary expertise, and that will consume a large quantity of manpower. At the start of the project, we expect to organise this work area via *brainstorming* meetings during which we will exchange ideas and background knowledge, and will explore innovative concepts and fundamental networking paradigms. Each partner will also work individually on specific areas of autonomic networking in order to explore in details a targeted part of the future autonomic network architecture. Overall, the scientific objective will require a large amount of manpower, which is reflected in the effort form of section 9.1.

In parallel, the technical objective of ANA, i.e. *to build an experimental autonomic network architecture and to demonstrate the feasibility of autonomic networking within the coming 4 years*, focuses on the implementation of networking functional blocks, and on the integration, deployment, and evaluation of the large-scale ANA testbed. This overall process is expected to be time consuming since it deals with implementation and system issues, integration of code, on-field deployment of equipments, and evaluation and measurements techniques. The technical tasks of ANA therefore concentrate a high proportion of the overall project manpower. Overall, each partner plans to contribute to ANA according to the following descriptions.

9.3.1 ETH Zurich

ETH Zurich, specifically the Communication Systems Research Group, has got the required junior and senior researchers for this project. During the project, additional students might be added to the project team.
The ETH team will be involved in all work packages, as ETHZ is the project coordinator. The project coordinator is a senior researcher and will also invest a large amount of his time for dissemination and exploitation tasks. ETH will lead and contribute to the monitoring task of work package 4. In this activity, ETH will build, together with the other partners, a monitoring architecture suitable for the autonomic network architecture. Members of the team will also participate in other tasks throughout the project where they use their experience in protocol design or routing, transport and service discovery tasks.

9.3.2 University Basel

UBasel and its Computer Networking Group will have two senior researchers and one junior research working on the ANA project. Because of the group's involvement in teaching computer networks and mobile code, it will be possible to involve student as

ANA testbed users and to let students perform small semester projects two years into the project.
UBasel is co-coordinating the ANA integrated project together with ETHZ and serves as backup. Inside the project, UBasel's main activities are in task 1.4 (communication mechanisms) and task 4.2 (Autonomic applications & migration of legacy nodes/applications), also leading the core work package 1 (architecture). Other involvements include tasks regarding dissemination and state of the art.

9.3.3 NEC

NEC is the leading industrial partner in the ANA project. NEC provides two senior and one junior researcher to this project. Leading WP2, NEC has got a major influence on the general architecture of the autonomic network design.
Novel network architectures are in the center of interest of NEC's future product lines. The researchers attributed to the project are very experienced in the field of network and system design and will contribute their knowledge but also their industrial networking to the project. Hence, NEC will also contribute to the dissemination and exploitation tasks during the project.
Additional effort will be put in the testbed design and the exploration of the new Autonomic Network Architecture in WP4.

9.3.4 Lancaster University

Lancaster University, Computing Department will allocate two researchers dedicated to the goals of the ANA project. During the project additional researchers funded outside the project will participate. Permanent members of the systems research group whose interests fall in the subject areas of ANA (Prof. D. Hutchison, Dr. A.C. Scott and Dr. A. Mauthe), as well as visiting Prof. J. Sterbenz, will be actively involved in the research, planning, and coordination of the project. Areas of contribution of the Lancaster team will be in testbeds, routing and data transport, network resilience and survivability, function composition, self-organisation and optimisation. A significant amount of effort will be focused (in collaboration with other partners) in the development of the ANA node network subsystem and the resiliency aspects of ANA, which correspond to the tasks that Lancaster will lead. Finally, Lancaster plans to invest effort and expertise in the coordination of WP5 and planning of the testbed.

9.3.5 FOKUS

FOKUS will provide two senior researchers and one junior researcher to the project. Strong relationships to the Technical University of Berlin (FOKUS has three associated chairs) open the opportunity to involve additional students into ANA.
FOKUS will contribute to task 1.5 by the analysis and definition of a information flow infrastructure to propagate various context related information through an autonomic network. FOKUS will furthermore lead a task in work package 3 on the design and implementation of a supervision subsystem for network compartments that allows for a flexible reaction on error situations and thus enables for self-healing capabilities.

9.3.6 University of Liege

The Research Unit in Networking (RUN) of ULg will provide one junior researcher and one post-doc researcher to the project. Several other researchers/students from the team will also contribute to the project objectives, and the team will be supervised by one professor. One expert on supervised learning from ULg's AI team will also collaborate with RUN.

In this project ULg will be leading WP3 and task 3.2, where it will mainly contribute to make ANA a self-aware and self-optimized architecture, able to learn from its monitored data. ULg will also be involved in tasks 1.4, 2.3 and 2.5, where it will contribute to add service discovery features to the architecture and to deploy customized communication structures (overlays) automatically.

9.3.7 UPMC

UPMC and specifically the Network and Performance analysis group of the LIP6 research lab have asked for one junior and one senior researcher for this project. During the project, additional students (mainly master students doing their internships) will be added to the project team. At least three professor of UPMC will be involved in the researches pursued in ANA projects. These professors will supervise the junior and senior researchers and coordinate the activities to reach the goals defined in the ANA project.

UPMC/LIP6 will be mainly involved work packages 2, where in it will lead task 2.1 about routing and transport. In this activity, UPMC/LIP6 will build, together with the other partners, new routing and data transport concepts that will be suitable for autonomous and self-organising networks. It will also contribute to self-organisation of the autonomous network as well as the monitoring task where the experience of LIP6 will be valuable.

9.3.8 NKUA

The Advanced Networking Group of the Communication Networks Laboratory will provide one junior and one senior researcher for the project. Several other researchers from the Group will interact with them, as the Group is focusing on aspects that are related to NKUA's work for the ANA project. Occasionally, and as needed, other researchers/Ph.D. students will partially contribute to this effort as well. Finally, one professor with extensive experience in networking will coordinate the ANA research effort of NKUA's team.

In the ANA project, NKUA will be involved in Tasks 2.1 (Routing and Transport), 2.3 (Service Dissemination) and 2.4 (Self-Association and Self-Organization). To these tasks, NKUA will bring its extensive expertise in ad hoc routing protocols, scalable information dissemination and clustering algorithms, resource allocation policies and performance evaluation.

9.3.9 University of Oslo

The Distributed Multimedia Systems Group at the University of Oslo will fund through the project a PhD student and a Post.Doc. Furthermore, additional part-time students might be added to the project team.
The group will have a focus in the project on monitoring, customisable communication structures and their application for collaborative monitoring. Therefore, the groups effort will be concerned with these issues during all project phases, i.e., in the starting phase in the requirements analysis (as task leader), during the architecture development in Task 1.5 (Information flow relationships), and during the development in the two core technical tasks, i.e., Task 2.5 (Customization of communication structures) as task leader and Task 3.1 (Monitoring), and during the final integration and evaluation in Task 4.2 (Testbeds, Prototypes, Data collection and Analysis).

9.3.10 Telekom Austria

Telekom Austria will provide one senior researcher and one junior researcher to the project. They will provide the expertise of Telekom Austria in the fields of testbed deployments, especially wireless and mesh networks. The effort of Telekom Austria will therefore be mainly focused on testbed integration and deployment with the lead of task 4.1 that relates to the deployment of the testbed. Telekom Austria will also concentrate on the demonstration of autonomic networking in the specific area of wireless mesh networks.

9.3.11 University of Waterloo

University of Waterloo will provide one senior PhD student, one postdoc and minimum of two MSc. Students. They will provide expertise in autonomic communication architecture design, automated QoS-aware service provisioning, and self-optimization. The group has extensive past experience in user controlled lightpath provisioning, multi-domain service discovery and QoS-aware service composition and adaptation. The group's primary focus in this project is on the design and construction of autonomic multi-domain QoS-aware service provisioning architecture (Task 2.6) and large scale multi-domain service discovery (Task 2.3). The group will further contribute to self-awareness and self-optimization aspects (Task 3.2) in service provisioning.

10 Ethical Issues

The ANA project aims at designing technical systems. These systems do not have any effect on ethical and gender issues.

With respect to sensitive ethical problems, the ANA project consortium can confirm that by no means human beings, human biological samples, personal data, genetic information and animals are involved in the project work and aims.

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Appendix A Consortium Description

A.1 Participants and Consortium

ETH Zürich (Switzerland)

In this project, ETHZ participates through its Communication System Research Group (CSG). Staffed by 4 faculty members, 2 staff members and 15 graduate students, the CSG provides the necessary resources for a successful project. CSG conducts cutting edge research in the areas of active networking technologies, mobile networks, ad hoc and wireless networks and network security. The CSG is well connected with other research laboratories, but also with the leading industry (Siemens, IBM, Intel, national and international ISPs,…).Through its large experience in participation in EU projects and its outstanding research records, the CSG is very well suited for the research and development tasks of this ambitious project as well as for the dissemination and exploitation tasks.
Concerning the project management tasks, the Coordinator will be supported through dedicated and professional project management division at ETH Zurich that includes highly qualified business management personnel, accountants, lawyers, and individuals specializing in personnel and gender issues. Support is also given by Euresearch Zurich, a dedicated office in the central administration of ETH Zurich supporting researchers since the 4th framework program.

University of Basel (Switzerland)

The Computer Science Department of the University of Basel is the youngest CS Department in Switzerland: It started in 2002 with a computer science curriculum according to the Bologna model and is part of the faculty of natural sciences. The Computer Networks Group is headed by Prof. Tschudin who has a long track record in networking, especially protocol stack architectures, mobile code and active networking, security and wireless networking. The profile of the group is both conceptual and architectural (active packet languages, selector networks, and network pointers) as well as systems oriented (e.g. wireless ad hoc routing protocol design, implementation and experimental evaluation). Recently, research results have been published on resilient protocol implementations and the use of genetic programming for the configuration and evolution of network configurations.
As the main initiator of this integrated project, UBasel is leader of WP1 (architecture) and task 1.4 (communication mechanisms) which corresponds to the group's history in active networking and architecture related publications The system profile and experience

with novel routing approaches using underlays is reflected in UBasel leading task 1.4 (autonomic applications and migration of legacy applications).

NEC (UK)

NEC is a leading global manufacturer and service provider of telecommunication, computer and electronic devices, and it began business in Europe in the early 1970s. The Network Laboratories in Heidelberg, Germany have been established in 1997, as NEC's second research facility in Europe.
The Laboratories place special emphasis on software-oriented research and development for the next generation Internet. New communication architectures and protocols supporting multimedia and mobility over the next generation Internet, together with intelligent Internet services and network management solutions are the core of our work. The laboratories have quickly become a recognized partner in various collaborative research and development projects conducted jointly with European service providers, technology vendors and academic research groups. Less than 4 years after their inception, the labs are leading contributors to the European Union's Information Society Technology program (EU IST), as well as various national German R&D activities. Its researchers have shown their strong leadership competence in the context of several IST projects, such as Ambient Networks, Daidalos, MOME, MobiVAS and Mobilife. NEC Heidelberg staff also actively contributes to scientific conferences as well as standard organizations like IETF, 3GPP and IEEE.
Due to the ever increasing complexity of today's and future network and communication systems and the growing cost that is involved in operating and managing those systems, the Heidelberg laboratories have already started to research into novel, *automatic* and *adaptive* network management and communication solutions. As a result of the strong interest in this area, the laboratories have further adopted the vision of autonomic network management and communications as one of its key areas of research.

University of Lancaster (UK)

Lancaster University, Computing Department has a strong international reputation for its research in the area of Networked and Distributed Systems, covering a broad range of areas (wired and wireless) including multimedia content delivery across networks, mechanisms to assure QoS in networked systems, mobile (IPv6) systems, reflective middleware, programmable and active networking, and autonomic network systems management. Its strength has been acknowledged by the recent International Review of UK Computer Science that cited Lancaster as one of only a handful of centers undertaking "leading edge systems research", while at the same time it is widely recognized as the UK's premier centre for mobile computing research. This work has attracted strong support and collaborations from industry such as BT Labs, Microsoft, Orange, Cisco, HP Labs, France Télécom, Lucent, Intel, Agilent Labs, Telekom Austria, and ETRI in S. Korea. Lancaster is also a central participant in EU/IST funded research projects, and several R&D projects funded by the UK Engineering and Physical Sciences Research Council (EPSRC).

The tasks in which Lancaster proposes to participate relate to the design, development, and testing of the ANA node communications system, as well as the low level mechanisms and protocols that will enable the effective participation and organisation of ANA nodes in network structures. Two research areas are particularly relevant as foundations for autonomic networking. First, Lancaster University has been in the forefront of research in active and programmable networks by actively participating in the UK EPSRC funded "PROGNETS" program, and in 2 industry funded projects (Alpine, LandMARC) in which a total of four different active node platforms were developed. In addition, visiting Professor J. Sterbenz (also at the University of Massachusetts in the US) was actively involved in the US DARPA-funded Active Networks program. Second, Lancaster Professor D. Hutchison and Professor J. Sterbenz have undertaken a new research thrust in resilient networks (including survivable and disruption-tolerant networking); J. Sterbenz was a PI in the US DARPA funded SUMOWIN (Survivable Mobile Wireless Networks) program. This unique expertise and strong background in (mobile) systems and active network research, as well as the experience in design, analysis, and prototyping of the foundations of autonomic networking, justifies the leadership of task 2.2 that will deliver the ANA basic communications subsystem, and also leadership in task 4.4 to provide autonomic network resilience.

Finally Lancaster's long-standing experience and involvement in infrastructure projects (6Bone, Bermuda, MSRL Testbed, 6Net, CLEO, and more recently UK Light), explains the coordinating role as work package leader in WP4.

Fraunhofer Fokus (Germany)

FOKUS will bring to the project its notable experiences in system testing and management for autonomic communication networks, for which it will assume the lead. In particular, FOKUS attends with two departments at the ANA project.
The Competence Centre for **Modeling and Testing of System and Service Solutions (MOTION)** focus on advanced methodologies and techniques for design, evaluation, and testing of IT systems and services and has a strong expertise and reputation these fields. A newly founded subgroup of MOTION is Autonomic System Engineering. MOTION's experience will be of help in WP3 for the definition and implementation of a distributed supervision subsystem for network compartments.
The research activities of the Competence Centre for **Next Generation Network Infrastructure (NGNI)** focus on new network architecture and service provisioning paradigms that departs from an ALL-IP based approach. Its unique expertise in this field will contribute to the project in WP1 with the analysis and definition of network information flows.

University of Liège (Belgium)

Founded in 1817, the University of Liège (ULg) is the only public Community-sponsored university in the French-speaking part of Belgium, which offers a complete range of university courses at undergraduate and post-graduate levels. In this project, ULg will participate via the RUN (Research Unit in Networking) group of the Department of Electrical Engineering and Computer Science (EECS) from the Faculty of Applied Science. Research in RUN bears on traffic engineering, MPLS, mobile communication, congestion control, multicast, and active/programmable networks. RUN has been involved in European projects since the outset in 1983, successively in ESPRIT, RACE, ACTS and IST. It has also participated in 5 COST actions. RUN is currently involved in the European E-NEXT NoE and several other federal or regional projects in Belgium.
In this project ULg will be leading WP3 and task 3.2, where it will mainly contribute to make ANA a self-aware and self-optimized architecture, able to learn from its monitored data. ULg will also be involved in tasks 1.4, 2.3 and 2.5, where it will contribute to add service discovery features to the architecture and to deploy customized communication structures (overlays) automatically.
ULg is currently leading a task force of the E-NEXT NoE on traffic engineering and coordinates the development of an open-source traffic engineering toolbox (TOTEM) for network optimisation, which are central topics of WP3. ULg has also started the design of a lightweight active network platform (WASP) suitable for service discovery and p2p networking, which is useful in the context of WP1 and WP2.

Université Pierre et Marie Curie (France)

The University Pierre & Marie Curie, located in Paris, is the largest Scientific and Medical University in France. LIP6 is one of the largest computer science laboratories in France (>350 researchers) covering a wide spectrum of topics ranging from theoretical computer science to VLSI, among them, the Network and Performance group covers issues related to networking. LIP6 is a lab associated with CNRS (National Scientific Research Center).
LIP6 will mainly contribute to Work Package 2, and apply its experience in wireless routing and large-scale dissemination to the goals of this work package. It will in particular contribute to the design of routing scheme, protocols for self-organisation, and service discovery in autonomous networks. Moreover, the research work done by LIP6 in new communication paradigms such as network coding will also be beneficial to both WP2 and task 1.3. Another task where LIP6 intends to contribute is task 3.1 which deals with monitoring, i.e. and area where the expertise of LIP6 in Internet measurements analysis, and in particular in traffic matrix estimation and global network monitoring will be useful.
The network and performance (NP) group aims at developing a vision for the future Internet as well as design solutions to shape and manage it. The target of the group is the control of ubiquitous, mobile and versatile networks that expand everywhere in our private and professional environments. The core of our work concerns problems related to multimedia and mobile networks, resource management, scalability, ambient networks

and peer-to-peer. In particular significant work is developed in the area of large scale routing, auto-configuration and Internet measurement. Our contributions also include development, experimentation and test-beds (IPv6, Mobility, QoS, Multicast).
Moreover, the group maintains a high number of academic cooperation, was instrumental in the establishment of the COST community in networking (COST237, COST264) and more recently in E-NET (FP5 Thematic network) and ENEXT (FP6 NoE), and plays also a critical role of animation at the national level. The group also develops a modern approach of research in networking, through basic research and transfer activities, in strong cooperation with worldwide academic partners and industrial leaders. It is also the core of Euronetlab, a joint laboratory between industrial and academic partners.

National and Kapodistrian University of Athens (Greece)

In this project, NKUA participates through the Communication Networks Laboratory (CNL) of the Department of Informatics and Telecommunications; the effort will be coordinated by the Advanced Networking Research (ANR) Group. CNL staff includes three faculty members, more than 8 post-doctoral researchers, more than 20 Ph.D. students and several M.Sc. students. CNL’s research is reflected in numerous publications in archival journals and conference proceedings – more than 150 publications in the last 5 years. Over the last 10 years CNL has participated in more than 10 European Projects and numerous national ones, in various aspects of networking. NKUA is a co-founding member of the Autonomic Communications Forum and has been extensively involved in FET consultations meetings aiming to define the “Situated and Autonomic Communication” research initiative. All these have brought considerable expertise and perspective that will be useful to the ANA project.
In the ANA project, NKUA will be involved in Tasks 2.1 (Routing and Transport), 2.3 (Service Dissemination) and 2.4 (Self-Association and Self-Organization). To these tasks, NKUA will bring its extensive expertise in ad hoc routing protocols, scalable information dissemination and clustering algorithms, resource allocation policies and performance evaluation.

University of Oslo (Norway)

The Distributed Multimedia Systems Research Group at the University of Oslo has strong experience in the area of flexible and adaptive transport protocols and middleware, including adaptive overlays for content distribution. Furthermore, the group is addressing the integration of networking, middleware, and data management issues, for example by using classical database management systems and modern data stream technology for traffic analysis and network monitoring. Based on this expertise the group will well prepared to lead the efforts towards customized communication structures in Task 2.5 and to strongly contribute to the monitoring related tasks in the project.
As an academic institution active in teaching and research, the DMMS group is interested in the ANA project to gain new insight, develop new solutions and publish results in premier conferences and journals. The group will use the project to stimulate

collaboration with the international research community, and increase the project's impact, by making concrete project results available in the public domain (principally APIs). With respect to teaching, the project will provide research topics and challenges for PhD and Master students, and so create mobile human capital for the further dissemination of knowledge. Furthermore, the experiences and results of the project will form useful examples and case studies for graduate level courses.

The DMMS group collaborates closely with other leading European research institutions, e.g., in the E-Next Network-of-Excellence on Emerging Networking Experiments and Technologies (6th Framework Programme, IST), and in the European Science Foundation Programme MiNEMA on Middleware for Network Eccentric and Mobile Applications. Current projects of specific relevance to ANA are the CONCAVE, INSTANCE II and Ad-hoc InfoWare projects. In CONCAVE, we use and develop Data Stream Management Systems for network monitoring (on-line analysis). INSTANCE II is about content distribution infrastructures for News-on-Demand services, and develops an adaptive (i.e. resource-aware, QoS-aware and topology-aware) overlay network. The Ad-Hoc InfoWare project is a nationally funded project in which DMMS co-operates closely with Thales. The project specifically addresses development of middleware services for mobile ad-hoc networks (MANETs), in the challenging context of support for emergency and rescue workers in the field.

Telekom Austria (Austria)

With revenues of approximately EUR 4 billion and roughly 14,000 employees in 2003, Telekom Austria is the largest telecommunications company in Austria and one of the leading corporations in this country. The Group has two main business areas: the Wireline segment encompasses fixed line telephony, data and Internet. The wholesale unit is responsible for business operations with reseller customers such as alternative fixed line operators, Internet service providers and mobile communications companies. The retail unit is responsible for business and residential customers. Besides fixed line telephony in Austria, the wireline segment comprises data and IT solutions.

As a national innovation leader in the ICT area, Telekom Austria manages the largest network, including access, metro and core portions of the network. We have participated in nationally funded R&D projects targeted at Network Management Issue in framework of the k-plus programme. Especially, the shift to Next Generation Networks Process Support Systems is to be of major importance. In order to understand the impacts of new networking concepts, such as Grid of autonomic networks, we see the need to identify the requirements for seamless service provisioning in order to devise viable solutions.

University of Waterloo (Canada)

University of Waterloo is renowned for its innovation and commitment to advancing knowledge. For the 11th year in a row, Waterloo has been recognized (Maclean's national survey) as the best overall and most innovative university in Canada. In the areas of network and distributed system research, University of Waterloo researchers have been long active in the design and analysis of fast packet switches; routing, flow and congestion control; end-to-end network performance analysis; call admission control and traffic management; services management; business and service performance modelling and metrics; pervasive computing and ubiquitous middleware design; component-based software engineering; user-centric network provisioning and configuration; modelling and analysis of discrete-time queuing systems; congestion control in LAN/MAN interconnection networks; hybrid wireless/wired networks; network management; self-managed and intelligent network systems; enabling technologies for electronic services; mobile applications; and techniques and tools for debugging distributed applications.

The network and service management research group, lead by Prof. Raouf Boutaba has accumulated extensive research experience over many aspects of self-managed and intelligent systems. The group's focus on establishing autonomic management concepts was first started in 1995, resulting in many publications over the last decade. The group has always been highly interactive with major industry partners (e.g. Nortel networks, Bell Canada, Alcatel, CANARIE etc.), evident in many successful projects in the past. Presently, the group is undertaking investigations in multi-domain service naming, multi-domain service/resource discovery, and autonomic multi-domain service composition and provisioning, as core functions supporting an open autonomic service platform.

A.2 Sub-Contracting

We do not yet foresee any sub-contracting of activities.

A.3 Third Parties

We do not yet foresee any involvement of third-parties collaborators.

A.4 Competitive Calls

We do not yet foresee any future call for new contractors. However, the ANA consortium is currently studying the possibility to add a new partner before the end of the negotiations phase.

A.5 Funding of third Country Participants

The ANA consortium does fund any non-EU participant. However, the University of Waterloo, Canada, is part of the consortium.